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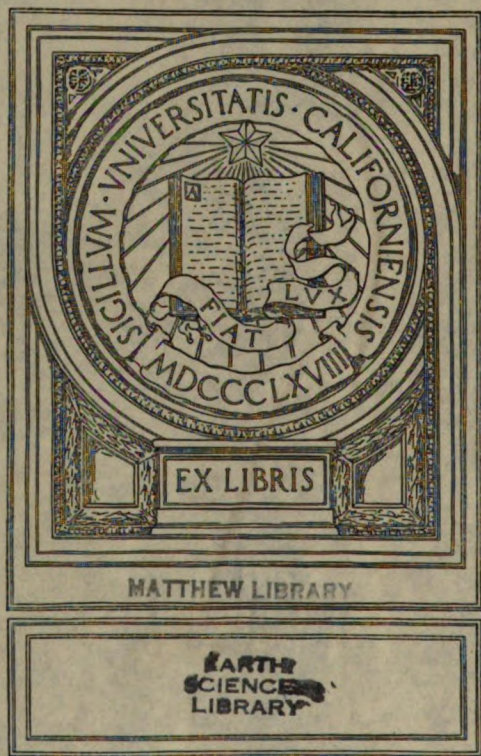
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NEW AMERICAN PALEOZOIC OSTRACODA
PRELIMINARY REVISION OF THE BEYRICHIIDÆ, WITH
DESCRIPTIONS OF NEW GENERA

BY

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NEW AMERICAN PALEOZOIC OSTRACODA.
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DESCRIPTIONS OF NEW GENERA.^a

By EDWARD O. ULRICH,
Geologist, U. S. Geological Survey.
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INTRODUCTION.

As defined in modern text-books, the Paleozoic family of Ostracoda, Beyrichiidae, embraces a large and constantly growing assemblage of genera and species. The unwieldiness of the typical genus *Beyrichia* became apparent some forty years ago, when T. Rupert Jones, the well-known and highly conservative English authority, and H. B. Holl first suggested the separation of the "simplices" as a distinct generic group under the name *Primitia*.^b At a later date these authors proposed the separation of the less sharply defined "Corrugatæ" group, typified by *Beyrichia wilckensiana*, under the name *Klædenia*.^c In the same paper they propose the genus *Bollia*,^d and in the next succeeding number of that periodical two other generic groups are distinguished as *Strepula*^e and *Placentula*.^f

Working independently, Jones had also instituted the genus *Kirkbya*^g for a Permian species thought to have relations to the Bey-

^a For previous articles of this series see Jour. Cincinnati Soc. Nat. Hist., XIX, 1900, pp. 179-185, and Proc. U. S. Nat. Mus., XXX, No. 1446, 1906, pp. 149-164, pl. xl.

^b Ann. and Mag. Nat. Hist. (3), XVI, 1865, p. 415.

In 1855 (Ann. and Mag. Nat. Hist. (2), XVI, p. 85), Jones divided *Beyrichia*, as then defined by him, into three groups, (1) "simplices," including the forms subsequently referred to *Primitia* and allied genera; (2) "Corrugatæ," with *B. wilckensiana* as the type of the group, and (3) "Jugosæ," including, besides *B. klædeni*, the type of the genus, also certain Ordovician species subsequently referred to *Tetradella* and *Ctenobolbina* by Ulrich.

^c Ann. and Mag. Nat. Hist. (5), XVII, pp. 347, 362.

^d Idem, p. 360.

^e Idem, p. 403.

^f Idem, p. 407.

^g Trans. Tyneside Nat. Field Club, IV, 1859, pp. 129, 134, 136.

richiidae. Later, in their papers on Carboniferous and Permian Ostracoda, Jones and Kirkby, while maintaining that *Beyrichia* is the genus under which the majority of the late Paleozoic species with grooved or sulcate valves should be placed, yet thought it necessary to distinguish, first the two groups *Beyrichiella* and *Beyrichiopsis*,^a and a few years later *Synaphe*.^b Finally, Jones separated the binodose *Primitia* from the more simple types, as *Ulrichia*,^c and the most simple, nonsulcate types, as *Aparchites*.^d

In 1890 the senior author of the present paper published the first results of investigations begun in the hope that they might end in a complete revision of the American Paleozoic Ostracoda. For various reasons the realization of this hope has been greatly delayed, and seems yet far in the future. In the first place the effort to procure material for study proved so overwhelmingly successful that the task assumed proportions quite beyond expectations. The unusual difficulty of the subject was recognized in the beginning, but with this unsuspected expansion of the material its difficulties seemed to grow greater and greater, while the mere description of the new and the revision of the old species has itself become a formidable piece of work. Another distressing obstacle was the necessity of finding some more accurate and satisfactory yet cheap method of illustration than had been employed hitherto. After long experimentation the writers believe they have finally solved the problem to the extent of offering at least serviceable if not uniformly artistic representations of the objects. However, these difficulties might all have been overcome long before this had not other more imperative duties consumed by far the greater part of the time that has elapsed since 1890. With this unavoidable drawback even future progress on the monographical treatment of the Paleozoic Ostracoda must necessarily continue to be somewhat sporadic.

In the first of Ulrich's papers on Ostracoda^e six new genera of *Beyrichiidae* were proposed. All of these, except *Jonesella*, were based on or include species previously referred to either *Beyrichia* or *Primitia*. Thus *Tetradella* was proposed for the *B. complicata* group, *Ceratopsis* for the horned but otherwise similar group typified by *B. chambersi*, *Ctenobolbina* for the *B. ciliata* group, *Drepanella* for a mostly undescribed section, but including *B. richardsoni*, and *Eurychilina* likewise for a largely undescribed group that was thought to

^a Geol. Mag., 3d Dec., III, 1886, pp. 434, 438.

^b Carboniferous Ostracoda from Ireland, Sci. Trans. Roy. Dublin Soc. (2), VI, 1896, p. 190.

^c Quart. Journ. Geol. Soc. London, XLVI, 1890, p. 543.

^d Ann. and Mag. Nat. Hist. (6), III, 1889, p. 384.

^e New and Little Known American Paleozoic Ostracoda, Journ. Cincinnati Soc. Nat. Hist., XIX, 1890-91, pp. 104-137, 173-211.

include at least one or two of the broadly margined Primitiæ. In a later publication^a two other simple Beyrichian genera were introduced, namely, *Primitiella* and *Halliella*, both founded on groups of species previously referred to *Primitia*. In the same work two somewhat aberrant Primitian genera, *Dilobella* and *Dicranella*, were also described.

Except *Synaphe*, all of these twenty-one genera have turned out to be reasonably natural generic groupings of the species previously, and in most part since, referred to the Beyrichiidae. With the recent multiplication of species through the discovery of new forms, it happens, as might be expected, that many of the species referred to the new genera, in the perhaps pardonable wish to emphasize the importance of the latter, now appear to belong to other not less well defined groups whose discrimination seems equally essential in an adequate classification of the wealth of specific forms now known. Because of the small range of diagnostic characters furnished by the shells, and more the inconstancy of these characters when a great group like Jones's Beyrichiidae is considered, it is impossible to formulate a broad family definition without going into undesirable detail. In the classification of living Ostracoda the family groups are based on anatomical modifications, the shells being scarcely considered. In fossil forms, obviously, the systematist is limited to modifications of the carapace. While the paleontologist's classification is, therefore, liable to grave misassociations, it should be remembered that the results of his efforts may be the best obtainable with the criteria available to him.

After a considerable study of living Ostracoda, the writers have been forced to the conviction that students of fossil species, especially those found in Paleozoic rocks, can not expect much help in their labors from even an extensive knowledge of living forms. The Cypridæ, even, which family, perhaps on account of lack of diagnostic characters, is at present thought to range back in time to early Ordovician, may yet be shown to be distinguishable from their presumed Paleozoic representatives. The Leperditiiidæ and Beyrichiidae, however, stand alone with no recognized close affinities to post-Paleozoic Ostracoda. These fossils, therefore, the paleontologist must work out for himself and do the best he can with the material at his command.

After the foregoing introductory remarks, some attempt to re-define the existing classification of Paleozoic Ostracoda is necessary. As the investigations are far from complete, the attempt must, to a considerable extent, be preliminary to the final effort to be made in

^a Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, pp. 629-693.

the proposed monograph. While confessing its preliminary nature, it should not be supposed that the results here presented are founded on studies of only a part of the species immediately concerned. On the contrary, the authors have taken into account not only every recognizably described or figured Beyrichian, but also a host of unpublished species. If a classification of any family or subfamily could be made final without first, or at the same time, subjecting all related families to a similar close investigation, the following might lay claim to being so. But as it is manifestly impossible to do this without extending the field of study beyond the point attained, the present contribution pretends to nothing better than a report of progress.

ORIENTATION OF THE VALVES.

The feature of the study of Paleozoic Ostracoda, about which the literature of the subject seems to show greatest variability and uncertainty among authors, is the determination of which of the two ends of the carapace and valves is the anterior. The rule most generally applied is to call the thicker end posterior. The present writers are agreed with this as a general principle or rule, but not as a law. Close comparisons, and especially exact analyses of the lobes of Beyrichian forms, showed so many exceptions to the rule that it seemed necessary to seek other and if possible more reliable criteria. The position and trend of the median furrow was the first feature to be investigated. Next the lobes were compared, and finally the outline of the valves. It was found that all three of these features afford more reliable evidence than does the relative thickness of the ends. With the application of these several criteria certainty and uniformity in orientation is attained, which, for purposes of description and comparison, is, after all, the chief essential; but there are no positive means, and perhaps never will be, of determining that the end of the fossil shell here called posterior did not really lodge the cephalic organs of the living animal. Still the propriety of the orientation adopted is supported by plausibility based on facts, the bearing of which seems incontrovertible if not wholly decisive.

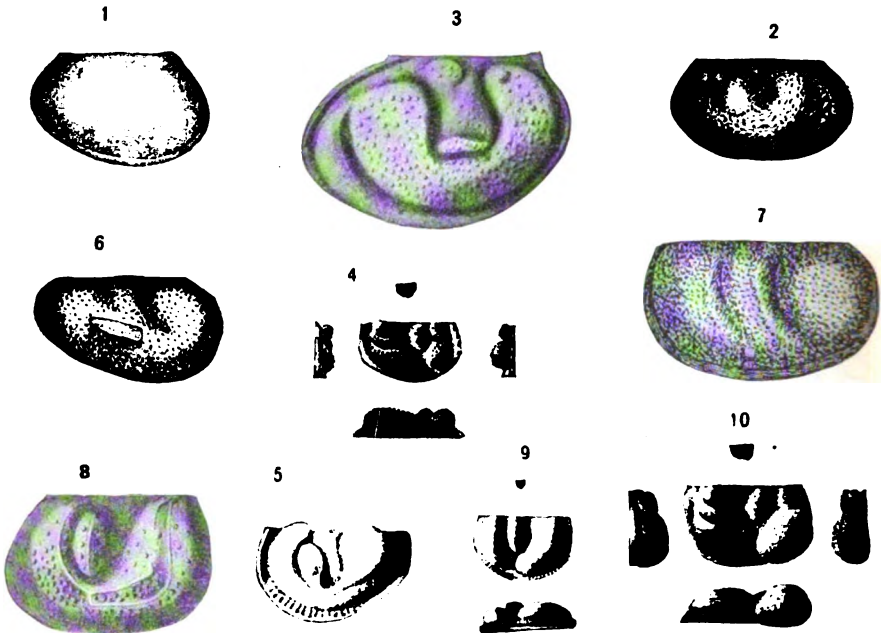
The principal line of evidence on which the orientation of the valves of *Beyrichia* and allied ostracods is based is derived from the position of the eye tubercle and the outline of the valves of *Leperditia*. That the small tubercle referred to was really connected with the visual organs of the animal of *Leperditia* is universally accepted by paleontologists. Hence we are justified in assuming that its location marks the anterior end of the carapace. Starting with this accepted fact, we note (1) that the eye-bearing end of the valve is almost always narrower than is the other end; (2) that the outline of the valves exhibits a backward swing so that a rec-

tangular line drawn from the middle of the straight cardinal edge divides the area of the valve into two more or less unequal parts of which the posterior is the longer and usually the greater. In other words, the valve is more or less oblique and its outline suggests a parallelogram rather than an oblong. Now, in by far the majority of Primitiidae and Beyrichiidae, the narrower and, rather less generally, the thinner half of the carapace is determined to be anterior also by the retrai swing of the outline and the comparative analysis of the nodes, lobes, and furrows.

The retrai (parallelogram) swing of the outline is perhaps the most persistent of the criteria, being applicable in even those cases (certain Leperditellidae) in which the valves are without nodes, their surface uniformly convex, and the ends nearly or quite equal in height. In many of the true Beyrichiæ the resulting obliquity of outline and inequality of the ends are both very inconspicuous (as, for instance, *B. kochii*, *B. maccoyiana*, *B. salteriana*), and in this genus it is often necessary in deciding which is the right and which the left valve to rely almost entirely on the correlation of the lobes. The data for this correlation are furnished by species like *Beyrichia clavata*, in which the "swing" and the difference in height of the two ends is sufficient to leave no doubt as to which is the anterior. A study of such a species shows that the median lobe is united below with the larger anterior lobe by means of a low and thin isthmus, and that the posterior lobe, if its ventral extremity extends forward at all, passes beneath this isthmus. It is observed further that the median lobe is located nearer the posterior than the anterior lobe; in other words, that the anterior furrow is almost without exception the wider of the two. Now, bearing these facts in mind, the anterior lobe is recognized at once as the one that is connected below with the median lobe. When this ventral union of the anterior and median lobes is obsolete, as in *B. tuberculata* and its immediate allies, the posterior lobe is usually recognized by the location of the median lobe which, as said, is commonly placed more or less distinctly behind the center of the valve. When this and all other tests seem indecisive, as they may rarely be in a species like *B. bronni* Reuter, then it is still possible to orient the valves by comparing minor nodes and furrows on the lobes with similar markings on less difficult species.

Additional evidence tending to show that the criteria relied on by the writers in orienting the valves of Beyrichiidae is furnished by the Chazy ostracod erroneously referred to *Beyrichia* by Jones under the name *B. clavigera*. This species, though strikingly like a *Beyrichia* in having a median node within the bend of a strongly curved, low ridge, seems yet to belong to the Leperditidae. It has an eye tubercle and agrees in all other respects, save the curved ridge, with species of

Isochilina, and the ridge even is represented in subdued form in *I. subnodosa*. The significant fact in this connection is that in this, we might almost say prophetic species, the above discussed criteria by



FIGS. 1-10.—1. LEFT SIDE OF ENTIRE SPECIMEN $\times 2$ OF *LEPERDITIA FABULITES* (CONRAD). ANTERIOR END INDICATED BY THE SMALL "OCULAR" TUBERCLE, ITS LESSER HEIGHT, AND BACKWARD SWING OF VALVE. 2. LEFT VALVE OF *ISOCHILINA? SUBNODOSA* ULRICH, $\times 3$, A NEARLY EQUAL FORM. ANTERIOR SIDE INDICATED BY OCULAR AND OTHER TUBERCLES, THAT WHEN PRESENT ARE ALWAYS IN FRONT HALF OF VALVES. 3. RIGHT VALVE OF *ISOCHILINA? CLAVIGERA* (*BEYRICHIA CLAVIGERA* JONES) $\times 10$, SHOWING THE OCULAR TUBERCLE AND MUSCLE SPOT OF *LEPERDITIIDÆ*, THUS DETERMINING WHICH IS THE ANTERIOR SIDE AND INCIDENTALLY AFFORDING A GOOD EXAMPLE OF RETRAL SWING. ORDOVICIAN (CHAZY SHALE), NEAR OTTAWA, CANADA. 4. LEFT VALVE OF *BEYRICHIA TUBERCLATA* (KLÖDEN) $\times 5$ (AFTER REUTER). ANTERIOR SIDE RECOGNIZED BY ITS INFERIOR HEIGHT, SLIGHT RETRAL SWING, AND BY CORRELATION OF NODES OF VALVE. 5. RIGHT VALVE OF *BEYRICHIA CLAVATA* KOLMODIN (AFTER KIESOW). ORIENTATION DETERMINED BY SAME CRITERIA AS IN FIGURE 4. 6. LEFT VALVE OF *CTENOBOLBINA ALATA* ULRICH, $\times 18$ (AFTER ULRICH). ANTERIOR END RECOGNIZED BY ITS TAPER AND BY THE RETRAL SWING OF THE OUTLINE. 7. LEFT VALVE OF *CTENOBOLBINA CILIATA* (EMMONS), $\times 18$ (AFTER ULRICH). ORIENTATION DETERMINED BY COMPARISON OF LOBES WITH THOSE OF *C. ALATA*, IN WHICH THE ANTERIOR END IS NARROWER AND THE RETRAL SWING MORE PRONOUNCED. 8. *BEYRICHIA (STEUERSLOFFIA) LINNARSSONI* (KRAUSE). RIGHT VALVE, $\times 15$ (AFTER REUTER). ORIENTED BY COMPARISON OF LOBES WITH THOSE OF *BEYRICHIA CLAVATA* AND *B. TUBERCLATA*. 9. *BEYRICHIA SALTERIANA* JONES, $\times 10$ (AFTER REUTER). THE ENDS BEING ALMOST EXACTLY EQUAL IN THIS SPECIES THE ORIENTATION OF ITS VALVES IS POSSIBLE ONLY BY COMPARISON OF ITS LOBES WITH THOSE OF OTHER *BEYRICHIAE*, LIKE *B. CLAVATA*. IN THESE, OTHER CORROBORATIVE CRITERIA ARE AVAILABLE, SUCH AS THE TAPER OF THE VALVES ANTERIORLY AND THE RETRAL SWING OF THE OUTLINE. ACCORDINGLY THE FIGURE REPRESENTS A RIGHT VALVE. 10. DIFFERENT VIEWS OF A LEFT VALVE OF *BEYRICHIA TUBERCLATA-BUCHIANA* REUTER, $\times 6$ (AFTER REUTER). THE EXAMPLE FIGURED POSSESSES THE VENTRAL POUCH, WHICH FEATURE REUTER AND OTHER WRITERS REGARD AS DISTINGUISHING THE FEMALE IN *BEYRICHIA* AND ALLIED GENERA. THE POUCH IS LOCATED INVARIABLY ON THE LOWER PART OF THE POSTERIOR LOBE.

which the right valve is distinguished from the left is supported by the evidence of the eye-tubercle.

Finally, the posterior location of the peculiar ventral pouch that Reuter and others have interpreted, we believe correctly, as ovarian inflations, is wholly in accord with the other criteria.

BEYRICHIA OF AUTHORS.

The genus *Beyrichia* was founded by McCoy in 1846.^a His "rough sketch" of the valves of the Irish species that first convinced McCoy that these fossils were bivalved crustacea and not trilobites gives a crude idea of the common Silurian form subsequently identified by Jones and others with *B. klædeni* McCoy. As McCoy ranks "*Battus tuberculatus*" of Klæden as a synonym of his *Beyrichia klædeni*, and as the two forms are distinguishable species, it is difficult to decide which of the two should rank as the genotype. However, as they are unquestionably congeneric, the point is of little consequence.

Subsequent authors have referred a considerable variety of Ostracoda to the genus. In fact, for many years it served as the temporary lodging place for nearly all of the Paleozoic species with furrowed or ridged valves. As noted above, a large part of these has been removed and distributed among other genera, but at the present writing no less than 150 species and varieties are still credited to *Beyrichia*. Many of these remaining species are not strictly congeneric with the type and hence will be removed, chiefly to new genera and to the long misunderstood *Klædenia*, the other more obvious departures from the generic type having been already mostly weeded out through the efforts of Jones, Holl, Kirkby, Krause, and Ulrich.



FIG. 11.—COPY OF MCCOY'S ORIGINAL SKETCHES OF BEYRICHIA KLÆDENI.

The genus *Klædenia* constitutes a close ally of the typical *Beyrichia*. The practical discrimination of the two groups, in certain cases at least, suggests that the boundary is artificial and probably results in occasional unnatural associations. But it is impossible to wholly escape this condition in any classification that is not too involved to be practical. Therefore, since the distinctive characters relied on in separating the two groups operate, as a rule, in apparent accord with genetic lines, *Klædenia* is accepted, with some justifiable modifications of the original diagnosis, as a useful designation. The comparatively few species about which there is doubt are provisionally left with *Beyrichia*.

Accepting *Beyrichia klædeni* and *B. tuberculata* as the types of the genus, and bearing in mind the ground to be occupied by the revised *Klædenia*, the restricted genus *Beyrichia* may be defined as follows:

^a Syn. Sil. Foss. Ireland, p. 57.

Genus BEYRICHIA McCoy, emended.

Beyrichia MCCOY, Synop. Sil. Foss. Ireland, 1846, p. 57.

Beyrichia BELL and FORBES, in Burmeister's Org. Trill., London, Suppl. App. p. 124.

Beyrichia MCCOY, Brit. Pal. Rocks and Foss., 1854, p. 135.

Beyrichia (part) JONES, Ann. and Mag. Nat. Hist. (2), XVI, 1855, p. 85.

Beyrichia (part) HALL, Nat. Hist. New York, Pal., III, 1859 [1861], p. 377.

Beyrichia (part) BARRANDE, Syst. Sil. du Centre Boheme, I, Suppl., 1872, p. 490.

Beyrichia (part) ZITTEL, Handbuch d. Pal., II, 1885, p. 553.

Beyrichia REUTER, Zeits. d. d. geol. Gesell., XXXVII, 1885, p. 628.

Beyrichia (part) JONES and HOLL, Ann. and Mag. Nat. Hist. (5), XVII, 1886, pp. 338, 345.

Beyrichia JONES and KIRKBY, Proc. Geol. Assoc., IX, 1886, p. 505.

Bollia (part) JONES, Ann. and Mag. Nat. Hist. (5), XIX, 1887, p. 408.

Beyrichia VERWORN, Zeits. d. d. geol. Gesell., XXXIX, 1887, p. 27.

Beyrichia (part) KRAUSE, Zeits. d. d. geol. Gesell., XLI, 1889, p. 17.

Bollia (part) KRAUSE, Zeits. d. d. geol. Gesell., XLI, 1889, pp. 13, 14.

Beyrichia MILLER, North Amer. Geol. and Pal., 1889, p. 534.

Beyrichia VOGDES, Annals New York Acad. Sci., V, 1889, p. 8.

Ctenobolbina (part) ULBICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1890, p. 111.

Streptula (part) KRAUSE, Zeits. d. d. geol. Gesell., XLIII, 1891, p. 498.

Beyrichia (part) ULBICH, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 657.

Beyrichia KOKEN, Die Leitfossilien, 1896, p. 40.

Beyrichia GURICH, Verh. d. Russ.-Kais. Mineral Gesell. zu St. Petersburg (2), 1896, p. 385.

Beyrichia GRABAU, Bull. Buffalo Soc. Nat. Sci., VI, 1899, p. 306.

Beyrichia ULBICH and BASSLER, Proc. U. S. Nat. Mus., XXX, 1906, p. 151.

Carapace comparatively large, 2 mm. to 5 mm. in length, semioval or semicircular to oblong in outline, with sharp dorsal and rounded ventral angles. Valves only moderately convex, strongly impressed with two vertical furrows, extending from the straight dorsal edge to the ventral portion of the valve so as to divide the intramarginal part of the surface into three unequal and unsymmetrical lobes. These vary considerably in size with respect to each other and with respect to their separation; also in the development of their ventral ends. The furrows may be much narrower or they may equal the ridges in width. The ovate median lobe is the most constant in form and size, usually the smallest, and ordinarily begins some distance beneath the dorsal edge. The anterior lobe, though generally the largest, is the most variable in size and form, being also often broken up into subsidiary nodes. The posterior ridge is, as a rule, the narrowest, runs nearly parallel with the posterior border, is rounded and thickest above, sometimes constricted near its middle, and often tapers to the vanishing point near the middle of the ventral edge. In other species it joins the ventral prolongation of the anterior lobe, in which cases commonly all three lobes are joined. When only two of the lobes are connected, it is, perhaps invariably, the median and the anterior. Ventral pouch (presumably of female) egg-shaped or

subglobular, as large or larger than either of the ordinary lobes, arising from the ventral part of the posterior lobe, hence located wholly or mostly behind the middle of the valve. A flange-like border around the ends and the ventral side. This may be narrow or wide, simple or rimmed, and variously ornamented with granules or spines. The flange overhangs the real contact edges which are beveled inward, the opposite edges meeting either flush or that of the right valve very slightly overlaps the edge of the left. Surface of valves smooth, granulose, punctate, or reticulate, or granulo-reticulate.

The following species have the characters of the genus as here restricted:

ORDOVICIAN SPECIES.

- | | |
|---|--|
| <i>Beyrichia</i> (<i>Steusloffia</i>) <i>acuta</i> (<i>Beyrichia erratica</i> , var. <i>acuta</i> Krause). | <i>Beyrichia</i> (<i>Steusloffia</i>) <i>signata</i> (<i>Beyrichia signata</i> Krause). |
| <i>Beyrichia</i> (<i>Steusloffia</i>) <i>antiqua</i> (<i>Beyrichia antiqua</i> Steusloff). | <i>Beyrichia tumida</i> (<i>Ctenobolbina tumida</i> Ulrich). |
| <i>Beyrichia granulifera</i> , new name (<i>Bollia granulosa</i> Krause). | <i>Beyrichia v-scripta</i> (<i>Bollia v-scripta</i> Krause). |
| <i>Beyrichia</i> (<i>Steusloffia</i>) <i>linnarssoni</i> (<i>Strepsula linnaessoni</i> Krause). | |

SILURIAN SPECIES.

- | | |
|--|--|
| <i>Beyrichia admixta</i> Jones and Holl. | <i>Beyrichia klædeni</i> McCoy. |
| <i>Beyrichia aequilatera</i> Hall. | <i>Beyrichia klædeni acadica</i> ^a Jones. |
| <i>Beyrichia baueri</i> Reuter. | <i>Beyrichia klædeni antiquata</i> Jones. |
| <i>Beyrichia baueri tripartita</i> Reuter. | <i>Beyrichia klædeni bicuspis</i> Klesow. |
| <i>Beyrichia</i> (<i>Steusloffia</i>) <i>beyrichioides</i> (<i>Strepsula beyrichioides</i> Jones and Holl). | <i>Beyrichia klædeni granulata</i> Jones. |
| <i>Beyrichia bolliana</i> Reuter. | <i>Beyrichia klædeni infecta</i> Jones. |
| <i>Beyrichia bronni</i> Reuter. | <i>Beyrichia klædeni intermedia</i> Jones. |
| <i>Beyrichia buchiana</i> Jones. | <i>Beyrichia klædeni intermedia</i> , subvar. <i>subspissa</i> Jones and Holl. |
| <i>Beyrichia buchiana angustata</i> Reuter. | <i>Beyrichia klædeni nuda</i> Jones. |
| <i>Beyrichia buchiana incisa</i> Reuter. | <i>Beyrichia klædeni protuberans</i> Boll. |
| <i>Beyrichia buchiana lata</i> Reuter. | <i>Beyrichia klædeni subtorosa</i> Jones. |
| <i>Beyrichia buchiana nutans</i> Klesow. | <i>Beyrichia klædeni torosa</i> Jones. |
| <i>Beyrichia clavata</i> Kolmodin. | <i>Beyrichia klædeni verruculosa</i> Jones. |
| <i>Beyrichia damesi</i> Krause. | <i>Beyrichia kochii</i> Boll. |
| <i>Beyrichia diffusa</i> Jones. | <i>Beyrichia lata</i> ^a Hall. |
| <i>Beyrichia dubia</i> Reuter. | <i>Beyrichia laevis</i> Klesow. |
| <i>Beyrichia grandis</i> Kolmodin. | <i>Beyrichia lindstromi</i> Klesow. |
| <i>Beyrichia granulosa</i> ^a Hall. | <i>Beyrichia maccoyiana</i> Jones. |
| <i>Beyrichia interrupta</i> (<i>Bollia interrupta</i> Jones). | <i>Beyrichia maccoyiana sulcata</i> Reuter. |
| <i>Beyrichia jonesti</i> Boll. | <i>Beyrichia moodeyi</i> , ^a new species, ^b |
| | <i>Beyrichia muldensis</i> Chapman. |
| | <i>Beyrichia nodulosa</i> Boll. |

^a American species.

^b This species is very similar to *B. maccoyiana* and is probably the American form referred to this latter species by Jones. It is distinguished by the greater isolation of the median lobe and the very finely punctated surface of the lobes. See Plate XXXVII, fig. 8.

Formation and locality.—Cayuga formation, near Cacapon, West Virginia.

Cotypes.—Cat. No. 53936, U.S.N.M.

- Beyrichia nodulosa expansa* (*B. lindstromi*, var. *expansa* Klesow).
Beyrichia noetlingi Reuter.
Beyrichia noetlingi conjuncta Reuter.
Beyrichia plagosa^a Jones.
Beyrichia plicata (*Entomis plicata* Krause).
Beyrichia pustulosa^a Hall.
Beyrichia reticulata (*Strepula reticulata* (limbata in text) Krause).
Beyrichia reuteri Krause.
Beyrichia salteriana Jones.
Beyrichia scanensis Kolmodin.
Beyrichia (*Steusloffia*) *simplex* (*Strepula simplex* Krause).
Beyrichia spinulosa Boll.
Beyrichia steusloffii Krause.
Beyrichia trilobata (*Entomis trilobata* Krause).
Beyrichia tuberculata (*Battus tuberculatus* Kloeden).
Beyrichia tuberculata bigibbosa Reuter.
Beyrichia tuberculata foliosa Jones.
Beyrichia tuberculata spicata Jones.
Beyrichia tuberculato-kochiana Reuter.
Beyrichia umbonata (*Beyrichia bolliana umbonata* Reuter).
Beyrichia waldronensis,^a new species.^b

DEVONIAN SPECIES.

- Beyrichia aurita* Richter.
Beyrichia devonica Jones and Woodward.
Beyrichia, new species (*B. klædnei* var. Jones).

Approximately 225 named species and varieties, varying in time from the Cambrian to the Permian, have, in the past sixty years, been referred to *Beyrichia*. Of the total number, only the seventy-three species and varieties listed above may be accepted as conforming strictly to the genus as here characterized. Only a few of these are Ordovician, and only two or three Devonian. The Cambrian species are regarded as widely different and probably not Ostracoda at all, while none of the Carboniferous species is strictly referable to the genus. As restricted, then, *Beyrichia* is preeminently a Silurian genus.

It is interesting to note further that only four of these species are as yet known in American deposits, and of these but one, *Beyrichia granulosa* Hall, is found in the Ohioan province, the other three occurring in the Atlantic and Polar provinces. All the remaining true *Beyrichia* seem to be confined to Baltic and British deposits, none of the central and southern European species being, so far as known, strictly referable to the genus. The list will be increased by two or three as yet unpublished east American Silurian species, but even with these the American representation is so weak that it is justifiable

^a American species.

^b Related to *B. moodeyi* and *B. maccoyiana*, but has a much broader marginal border, a rather longer median lobe, and a distinctly reticulate surface which is especially marked on the lobes. The species presents considerable resemblance to *Beyrichia reticulata* as figured by Krause, but differs in wanting the crest-like ridge. See Plate XXXVII, figs. 9, 10.

Formation and locality.—Niagaran (Waldron shale), Waldron, Indiana.
Cotypes.—Cat. No. 41660, U.S.N.M.

to regard *Beyrichia* as essentially a north European genus. The direct opposite is true of the group of Beyrichiidae typified by *B. wilckensiana* Jones, for which Jones and Holl subsequently erected the genus *Klædenia*. That is to say, the latter genus is much more strongly developed in America than in Europe.

About ninety of the species originally described as *Beyrichia* remain to be distributed among their proper genera. A large part of this number will be accounted for in the following discussions of the other genera of the family. But a considerable number will remain even then that for one reason or another cannot yet be definitely placed. In most cases it is lack of knowledge that suggests delay in deciding their systematic positions. A few, however, require further study and comparison, being too peculiar to fall readily into place.

The species here definitely referred to *Beyrichia* fall into seven, in part genetic, in part perhaps artificial groups. The first three of these, the *B. klædeni*, the *B. tuberculata*, and the *B. buchiana* groups, are made up entirely of unequivocal species of the genus. The other four groups, however, are more or less synthetic, and, though including species that cannot be clearly distinguished from *Beyrichia*, they are yet closely connected with species that must be referred to other genera. In other words, they represent different lines of development that seem to have originated in diverse Ordovician types but ended through what might be called convergent evolution in much more uniform stages. It appears further that in the decline of the genus a partial reversion to ancestral stages took place. Suggestive observations bearing on these points will be found in the following notes.

GROUP OF *B. KLÆDENI*.

This group embraces *B. klædeni*, *B. maccoyiana*, *B. bolliana*, *B. kochii*, *B. tuberculato-kochiana*, *B. moodeyi*, new species, *B. lindstromi*, and most of the forms described by various authors as varieties of the first-named species. Its valves are usually short, semi-elliptical in outline, and sharply lobed. The lobes are of medium thickness, the anterior one tending to enlargement and dissection, while the middle lobe is nearly as large as the posterior and commonly exhibits a tendency to union with the incurved ventral extremity of the anterior lobe. The posterior lobe is more or less acuminate and incurved below, but does not extend forward beyond the base of the median lobe. The type usually is shorter and always has somewhat thicker and more bulbous lobes than the *buchiana* section, and it is commonly shorter, with less dissected anterior and posterior lobes, and a longer median lobe than the *tuberculata* group. It constitutes, therefore, an admirable central type for the genus, and its

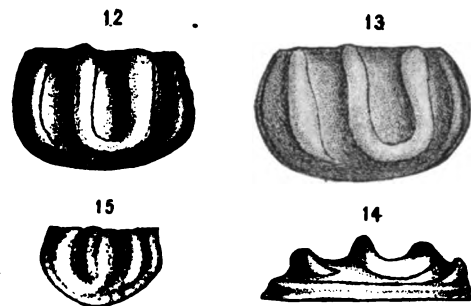
least synthetic, hence most characteristic phase. None of the species belonging to the group suggests genetic relations to species not included in the genus as here defined.

GROUP OF *B. BUCHIANA*.

In *B. buchiana* and its nearest allies and varieties the anterior and median lobes are joined, as commonly happens in *Beyrichia*, but the anterior lobe is thinner and the ventral connection proportionally thicker than usual, the combination giving to the united lobes a striking similarity to the horse-shoe ridge in the *B. ungula* section of *Bollia*. Indeed, *Beyrichia buchiana* and the Cincinnati *Bollia regularis* (Emmons) and *B. persulcata* (Ulrich) are sufficiently alike in general aspect to have induced so thorough a student of Ostracoda as T. Rupert Jones to refer a partially covered specimen of the last

to the Silurian *Beyrichia*. The resemblance might be regarded as indicating genetic affinity between the two, the younger *B. buchiana* being evolved through the continued and finally total obsolescence of the anterior marginal ridge of the *Bollia*.

Though admitting the possibility of such a derivation, it has yet seemed to the writers an improbable relationship. The marginal ridge is one of the most stable characters of



FIGS. 12-15.—12-14. LEFT VALVE AND SIDE AND EDGE VIEWS OF ANOTHER LEFT VALVE OF *BOLLIA REGULARIS* (EMMONS), $\times 30$. ARNHEIM BEDS OF RICHMOND GROUP, WAYNESVILLE, OHIO. 15. LEFT VALVE OF *BEYRICHIA BUCHIANA* JONES, $\times 8$ (AFTER JONES). THE FIGURES ARE INTENDED TO ILLUSTRATE THE POSSIBLE DERIVATION OF THE *B. BUCHIANA* GROUP OF *BEYRICHIA* FROM *BOLLIA*.

Bollia, and though its ventral part is often low and sometimes quite obsolete, there is no evidence to show that the anterior part is even lost entirely. The arrangement of the ridges in *Bollia* is bilateral with respect to a median furrow, in *Beyrichia* with respect to a median lobe. In *Bollia regularis* the anterior marginal ridge is paired with a less well-developed posterior ridge, the pair of median ridges uniting below as usual. In testing the possible derivation of *Beyrichia buchiana* from *Bollia regularis*, it should be remembered that in the *Beyrichia* it is the anterior and median lobes that are united, and that if the suggested derivation were a fact, it must have been by anterior shrinkage of the *Bollia* and final loss of the part bearing the anterior marginal ridge. Instead of this it seems certain that the stronger of the terminal ridges on valves of *B. regularis* is the anterior one, proving that in this species at least the conditions are the opposite of what they should be.

The *B. buchiana* group is characterized by its comparatively long shells, but passes by easy gradation into the *B. klædeni* group, the mere proportionate shortening of the valves sufficing to bring about some of the differences between them. On the other side it grades by thickening and division of lobes into the *B. tuberculata* section. *B. laucensis* Kiesow is regarded as an extreme member of the group, differing from the other species in the dissection of the anterior lobe and its separation from the median lobe.

GROUP OF *B. TUBERCULATA*.

This section of the genus comprises a number of species and varieties in which the anterior and posterior lobes are broken up by minor furrows, the posterior lobe into two, the anterior lobe into from two to six or seven node-like parts. Reuter's *B. buchiano-tuberculata* would represent about the simplest type and *B. pustulosa* Hall and *B. nætlingi* Reuter the most complex. The anterior lobe is, as a rule, larger than in other groups, and when not too much dissected, retains the "leg-of-mutton shape" pertaining to this lobe in the majority of the species of the genus. In the most simple species of the group the posterior lobe is sharply constricted about its midlength, or somewhat above this point, the upper bulb being usually considerably smaller than the lower. The anterior lobe in these is crossed obliquely by a single curved furrow dividing the vertical upper part from the much larger ventral portion. In the next stage of dissection (as, for instance, *B. tuberculata* and *B. bronni*) the posterior lobe is usually completely divided, while the anterior lobe is crossed by two parallel furrows instead of one. In further stages the lower and largest of the three divisions of the anterior lobe is broken up into a series of three nodes and the middle division commonly into two, while the upper may also be divided into two much smaller tubercles.

Except in the most simple species, which of course are not far removed from *B. klædeni* and *B. buchiana*, none of the lobes are connected ventrally. This fact sets the group somewhat apart from the majority of the remaining species here referred to the genus, and allies it to the subgenus *Steusloffia*. A coarsely granulose surface ornament of the lobes usually obtains except in the most highly dissected species. As a rule, the main lobes are well separated and the carapaces large, thus differing from the otherwise similar group of *B. salteriana*.

Respecting the derivation of this group of species, the problem seems at first sight very obscure. However, on closer analysis of the lobes and comparison with Ordovician genera, the possibility of its having sprung from *Drepanella* becomes more and more evident, so that finally the idea assumes the rank of high probability and needs but the discovery of one or two links to make it a certainty. To illus-

trate the supposed evolution, the lines of a *Drepanella* have been drawn in black over a figure of *B. tuberculata*. This shows that by merely dividing the sickle-shaped marginal ridge of *Drepanella* into a series of three or more node-like parts, the result is in essential accord with the structure characterizing the group of *B. tuberculata*. Above the submarginal ridge the valves of *Drepanella* have two persistent lobes corresponding to the median and anterior lobes of most *Beyrichiæ*. They may be dissected into subsidiary nodes (as, for instance, *D. crassinoda* and *D. nitida*) and are sometimes connected ventrally (*D. bigeneris*), as is commonly the case in the groups of *B. buchigna* and *B. klædeni*. The subsidiary nodes of the dissected anterior lobe in *Drepanella macra*, *D. crassinoda*, and *D. nitida* can be matched exactly in respectively *Beyrichia tuberculata*, *B. nætlingi*, and *B. baueri*. But the tendency to dissection of the median lobe exhibited by the oldest species of *Drepanella* is never observed in species of *Beyrichia*. Indeed, this lobe soon became the most constant feature for the whole family. Aside from this occasional difference,

the greatest distinction between *Drepanella* and the *tuberculata* section of *Beyrichia* is that, whereas in the former the outer sickle-shaped ridge is the most constant feature, in the latter it became through dissection the least stable.

The youngest unquestionable *Drepanella* known is the *D. richardsoni* of the Richmond in Ohio. In this the anterior end of the sickle-shaped submarginal ridge is thick and tends to connect with

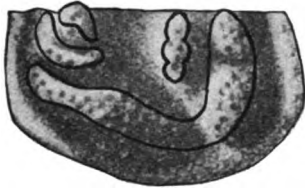
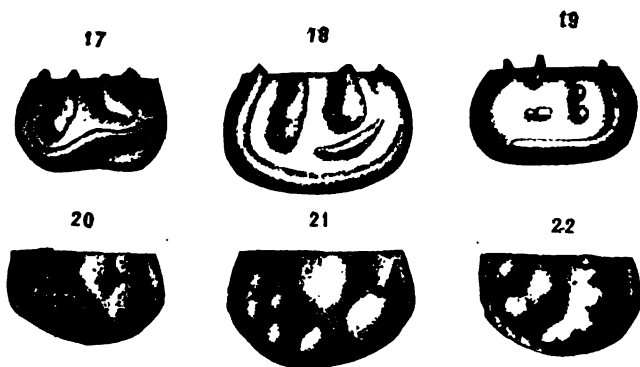


FIG. 16.—A LEFT VALVE OF BEYRICHIA TUBERCULATA (KLÆDEN), $\times 15$, WITH THE LINES OF A DREPANELLA DRAWN OVER IT.

the basal part of the expanded and prominent, though still partially dissected anterior lobe. Continuing this line of departure from the older, typical species of the genus, a stage might be expected in which the anterior lobe would be swollen to such a degree that the component nodes or tubercles of the earlier dissected stages would be entirely obscured. In fact, we have such a stage in a late Richmond species described by Ulrich as *Ctenobolbina tumida*. As stated in the discussion of that genus, the species is not a *Ctenobolbina*, the bulbous part of the carapace which was thought to correspond to the similarly bulbous posterior end of *C. ciliata* being, in fact, anterior. The original specimens of the species were not in condition to permit working out all its characters exactly, nor had any reason occurred at that time to lead the author to suspect that the swollen end of the carapace is anterior and not posterior. Such a suspicion, ending finally in conviction, arose only during the course of the present revision of the family. Recognizing the median lobe of *Beyrichia* in the small vertical node or ridge located well to one side of the middle

of the valve in *C. tumida*, and having learned that this is invariably situated *behind* the middle, no other course remained than to interpret the bulbous end as anterior.

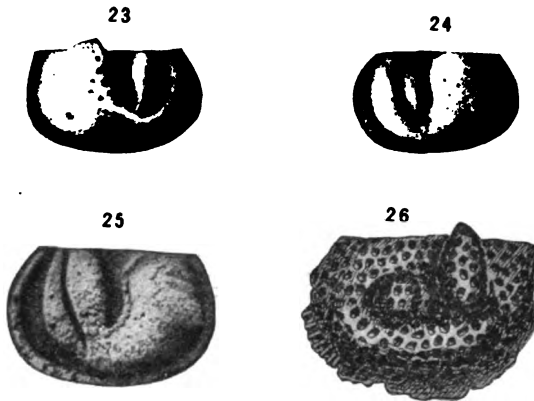
Having oriented the valves in this manner, the relations of *C. tumida* to *Drepanella richardsoni* became fairly clear; but even then it required a more perfect specimen than the original types to enforce conviction. This specimen, recently collected at Moreland, Kentucky, has a thick marginal ridge running from the post-dorsal angle to the middle of the ventral edge, where its further extent is lost in the ventral slope of the anterior bulb. But its anterior extremity reappears on the opposite side of the bulb as a distinct node. Taking essentials alone into account, the characters of *C. tumida* are not greatly different from those of *Beyrichia* like *B. protuberans*, *B.*



FIGS. 17-22.—17. RIGHT VALVE OF *DREPANELLA MACRA* ULRICH FOR COMPARISON WITH FIG. 20. LEFT VALVE OF *BEYRICHIA TUBERCULATA* (KLÆDEN). 18. RIGHT VALVE OF *DREPANELLA CRASSINODA* ULRICH FOR COMPARISON WITH LEFT VALVE OF *BEYRICHIA NOETLINGI* REUTER (FIG. 21). 19. LEFT VALVE OF *DREPANELLA NITIDA* (ULRICH) FOR COMPARISON WITH THE CORRESPONDING VALVE OF *BEYRICHIA BACERI* REUTER, SHOWN IN FIG. 22. (COPIED AFTER ULRICH AND REUTER.)

jonesi, or *B. clavata*, in which also the anterior lobe is the most prominent part of the valves and the posterior lobe extends forward beneath the middle and anterior lobes. Therefore, despite the rather strong dissimilarity in aspect, there seems really to be no very essential difference between *C. tumida* and *Beyrichia*. The posterior half is nearly the same in both, and only the great development of the anterior lobe gives the Ordovician species a strange look. However, as the writers are convinced that the latter is related genetically to unquestionable species of *Beyrichia*, and that the differences noted are not of greater importance than those obtaining between, for instance, the *B. tuberculata* and the *B. klædeni* groups, the species *tumida* is removed from *Ctenobolbina*, where it certainly does not belong, to *Beyrichia*.

The relations of *B. tumida* to the Clinton *B. lata*, suggested in 1894,^a have been confirmed in the present investigation. Though widely different in general aspect, the evolution of the latter from the former is regarded as not unlikely. In the rapid and sometimes extravagant mutation that is indicated, not only for the ostracoda but also in other classes of animals, at and immediately following the close of the Ordovician, it is readily conceivable that both the anterior and the posterior lobes of *B. tumida* might have been greatly reduced and thus to have brought about a temporary stage like *B. lata*.



FIGS. 23-26.—23. LEFT VALVE OF *DREPANELLA RICHARDSONI* (MILLER), $\times 10$, INTRODUCED FOR COMPARISON WITH *BEYRICHIA TUBERCOLATA*. UPPER BEDS OF THE RICHMOND GROUP, NEAR WILMINGTON, OHIO. 24. RIGHT VALVE OF *BEYRICHIA TUMIDA* (ULRICH), $\times 10$, SHOWING ITS DERIVATION FROM *DREPANELLA*. TOP OF RICHMOND GROUP, MORELAND, KY. 25. RIGHT VALVE OF *BEYRICHIA LATA* HALL, $\times 10$, FOR COMPARISON WITH *BEYRICHIA TUMIDA* AND *DREPANELLI RICHARDSONI*. CLINTON GROUP, NEW HARTFORD, N. Y. 26. RIGHT VALVE OF *TREPOSELLA LYONI* (ULRICH), $\times 20$, A DERIVATION OF *BEYRICHIA* IN WHICH THE POSTERIOR LOBE HAS BECOME OBSOLETE. (AFTER ULRICH.) ONONDAGA LIMESTONE, FALLS OF THE OHIO.

The Clinton species is chiefly remarkable because of the slight development of its posterior lobe. In the Devonian decadence of typical *Beyrichia* a similar obsolescence of the posterior ridge is noted in the modified stage represented by *Treposella lyoni* (Ulrich). At this time the *Beyrichiidae* assumed various atavistic expressions, some suggesting *Ctenobolbina*, others *Bollia*, while a third may recall *Tetradella*. In the partial obsolescence of the posterior lobe and the proportionate distinctness of

the loop formed by the ventral union of the median and posterior nodes, *B. lata* also suggests a *Bollia*.

GROUP OF *B. SALTERIANA*.

The species of this group do not, as a rule, attain the average size of those included in the *B. tuberculata*, *B. klædeni*, and *B. buchiana* groups. They differ rather obviously, too, from these other groups in the fullness of their lobes and the proportionate narrowness of the furrows. The departure from the more typical sections is toward *Klædenia*, in which the furrows are obscure or die out entirely in

^a Ulrich, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, p. 674.

the swollen ventral half of the valves. While clearly intermediate in character between typical *Beyrichia* and *Klædenia*, it yet seems unlikely that either was derived from the other through the *salteriana* group. On the contrary, a study of *B. salteriana* Jones, *B. reuteri* Krause, *B. plicata* (Krause), and *B. trilobata* (Krause) seems to indicate a closely knit line of development that diverged, like the *B. linnaarssoni* group, from some early stage of *Ctenobolbina*. The resemblance exhibited by *B. plicata* to *Ctenobolbina subcrassa*, for instance, is too close to be regarded as otherwise than genetic; and the agreement between *B. plicata* and *B. reuteri*, and between the latter and *B. salteriana*, is so intimate that a similar relationship seems undeniable.

Compared with the other sections of the genus, the *salteriana* group agrees best with the *B. tuberculata* group in the isolation of its median lobe. The dissection of the other two lobes occurring so generally in that group, however, is not even suggested.



FIGS. 27-30.—27. RIGHT VALVE OF CTENOBOLBINA SUBCRASSA ULRICH, $\times 20$. (AFTER ULRICH.) 28. RIGHT VALVE OF BEYRICHIA PLICATA (KRAUSE), $\times 20$. 29. LEFT VALVE OF BEYRICHIA REUTERI KRAUSE, $\times 15$. (FIGS. 28 AND 29 ARE COPIED FROM KRAUSE.) 30. RIGHT VALVE OF BEYRICHIA SALTERIANA JONES, $\times 10$. (AFTER REUTER.) THE FIGURES ILLUSTRATE THE RELATION AND PROBABLE DERIVATION OF THE BEYRICHIA SALTERIANA GROUP FROM A CTENOBOLBINA LIKE SUBCRASSA. TWO INTERMEDIATE STAGES ARE SHOWN IN FIGS. 39 AND 41.

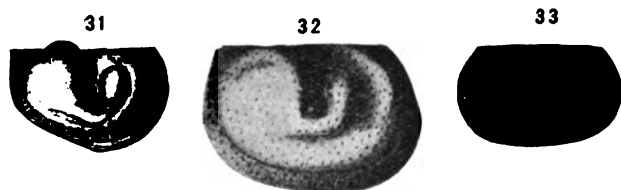
Beyrichia granulosa Hall, from the Waldron shale of Indiana, is a good American example of this section of the genus. This species is of exceptional interest because it is one of the few species of the genus that occur in Silurian deposits of the Ohioan Province.

GROUP OF *B. CLAVATA*.

Of the foregoing groups, those of *B. klædeni*, *B. buchiana*, and *B. tuberculata* represent the fully established and most typical stages of the genus. The group of *B. salteriana* evidently originated in some species of *Ctenobolbina* and probably is the stock from which *B. klædeni* was derived. It is also the only known group from which the genus *Klædenia* might have sprung. The small group of *B. clavata*, which includes *B. jonesii* Boll and possibly *B. umbonata* Reuter, likewise has a character suggesting an earlier genus, namely, the posterior ridge curves forward along the ventral margin, and, though attached to the slender isthmus connecting the anterior and median lobes, is often distinguishable as far as the antero-ventral angle where it merges into the great, pear-shaped anterior lobe. So

far as essentials go, the result is not unlike the Ordovician genus *Drepanella*, with its great, sickle-shaped marginal ridge.

Much similarity is traceable also between *B. clavata* and the synthetic *B. interrupta* group. The posterior ridge is not so well developed in that group, but in *B. v-scripta* and *B. granulifera* it is clearly suggested to where it is lost in the low anterior lobe; and just over its ventral part is the antero-median isthmus. Whether either of these resemblances are indicative of close genetic alliances can not be decided with the evidence now available. The youngest unquestionable *Drepanella*, *D. richardsoni* (Miller), of the Richmond group, analyzes more in accord with *Beyrichia tuberculata* than with *B. clavata*. As stated in another note, the union of the posterior lobe of *B. tuberculata* with the lower of the three parts of the anterior lobe (see figure) would give every essential of *Drepanella*. While the importance of the difference is recognized, and it is a fact that links establishing the relation are unknown, the writers, nevertheless,



FIGS. 31-33.—31. LEFT VALVE OF *BEYRICHIA CLAVATA* KOLMODIN. 32. LEFT VALVE OF *BEYRICHIA GRANULIFERA*, NEW NAME (*BOLLIA GRANULOSA* KRAUSE), $\times 15$. (AFTER KRAUSE.) 33. RIGHT VALVE OF *BEYRICHIA TUMIDA* (ULRICH), $\times 10$. THE FIGURES ILLUSTRATE THE RESEMBLANCE OF THE *BEYRICHIA CLAVATA* GROUP TO THE *B. INTERRUPTA* GROUP AND SHOW THE SIMILAR ANTERO-VENTRAL PROLONGATION OF THE POSTERIOR LOBE.

are convinced that the *B. tuberculata* section was evolved out of *Drepanella*.

Despite the unbroken antero-ventral continuation of the posterior ridge in *B. clavata*, the direct derivation of this species from *Drepanella* seems unlikely, except it be through *B. tumida* (*Ctenobolbina tumida* Ulrich).^a Derivation from something like *B. granulifera* and *B. v-scripta* is at least equally plausible. However, neither of these possible solutions is entirely satisfactory, so that for the present the origin of *B. clavata* must be left as undecided.

As for *B. umbonata*, which is somewhat doubtfully referred to this group, the alliance with *Drepanella* seems much more natural. Except that the valves are, on the whole, more convex, and the lobes thicker and less sharply defined, every other essential feature may be duplicated in typical *Drepanella* like *D. crassinoda* and *D. macra*.

Another drepanelloid Beyrichian and possible member or derivation of this group is the Devonian *B. kolmodini* Jones. This species has

^a See notes on *Drepanella richardsoni* and *Beyrichia tumida* on page 290.

a thick, yet sharply defined, sickle-shaped ridge with two separate rounded nodes above and a variable short ridge just within the anterior edge. Except the interiorly concave marginal border, smaller size, and proportionally narrow anterior end, the general aspect, especially in the matter of lobation, is highly suggestive of *Drepanella*. Here again, however, the writers doubt the reality of the suggested genetic relation. On the contrary, it is thought the true affinities of the species lie with other middle Devonian species that could not be suspected of alliance to *Drepanella* except in a very remote degree. These species, namely, constitute a peculiar group, described and mostly referred by Ulrich, as is now believed incorrectly, to *Ctenobolbina*. Conspicuous members of this group are *C. informis*, *C. antespinoza*, *C. spiculosa*, *C. cavimarginata*, and *C. insolens*. These species, it will be noted, vary greatly in general expression, and because of their spinosity, probably indicate decadence of the Silurian type of Beyrichiidae, and rapid evolution toward the establishment of the final, again comparatively long-lived type of the family. In the transition, various atavistic stages are indicated, some recalling *Ctenobolbina*, some *Bollia*, and others, like *B. kolmodini*, more nearly resembling *Drepanella*. Previously highly important and constant features have become most unstable, but through all the vagaries the steady evolution of the two rounded nodes which constitute the essential characteristic of the dominant and generically distinct later Paleozoic Beyrichian type is manifest. These two nodes, which represent the median and anterior lobes of typical Beyrichia, are well developed in *B. kolmodini*, but the general expression of the valves in this transitional stage in the development of the family is so at variance with that of the typical Silurian groups of *Beyrichia* that the writers have decided to recognize it by erecting the new genus *Hollina*.

Subgenus **STEUSLOFFIA**, new.

Beyrichia (part) of AUTHORS.

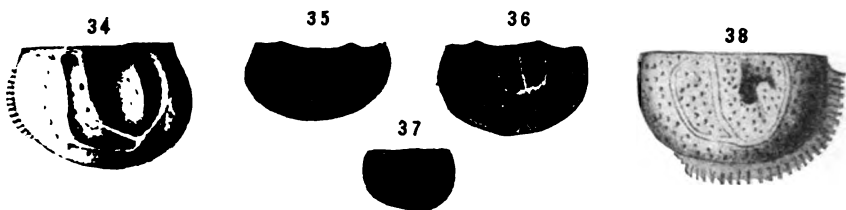
Strepula (part) of AUTHORS.

GROUP OF B. LINNARSSONI.

Beyrichia antiqua, *B. acuta*, *B. simplex*, *B. linnarssoni*, *B. signata*, *B. beyrichioides*, and probably *B. erratica* Krause, which is provisionally not included in the above list, constitute a peculiar group suggesting *Strepula* in having thin, elevated ribs or crests running over the surface of the valves. It is believed that these ribs served the purpose of strengthening the valves and that they are developed in genetically distinct groups of species. Depending primarily on the lobation of the valves and on their form in deciding questions of relationship, the group under consideration conforms in all essential respects with typical *Beyrichia*.

Beside the presumably dominating alliance of the *B. linnarssoni* group to *Beyrichia* s. s., and the suggested relation to *Strepula*, other in part apparently true alliances are indicated, in some by the arrangement of the superficial ribbing, in others by the form and disposition of the lobes. Thus the tetrameroid arrangement of the ribs in *B. erratica* and *B. signata* recalls *Tetradella*. The same may be said of certain more typical and possibly true strepulæ like *S. lineata* Krause and the two varieties described by Steusloff as *granulosa* and *separata*. The more simple *B. antiqua* Steusloff and *B. acuta* Krause are like certain species of *Ctenobolbina*. In the opinion of the writers, this resemblance is of real genetic significance, the indicated relationship and probable derivation of at least some *Beyrichiæ* from *Ctenobolbina* seeming fairly easy to establish.

In tracing out this relationship we begin, not with the genotype, *C. ciliata*, and the four or five closely allied species found in the Cincinnati rocks, but with the older Stones River and Mohawkian



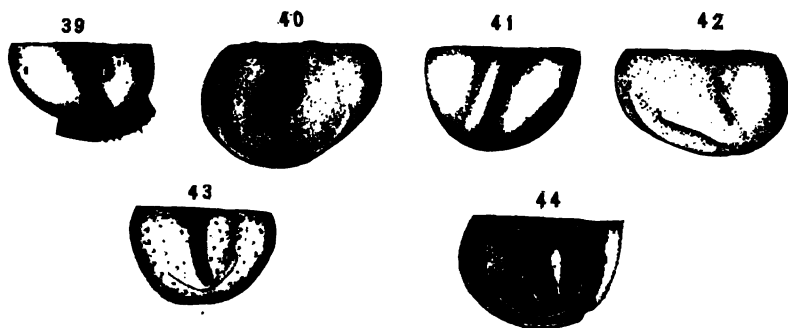
FIGS. 34-38.—34. LEFT VALVE OF BEYRICHIA (STEUSSLOFFIA) LINNARSSONI (KRAUSE). $\times 20$. (AFTER KRAUSE.) 35. RIGHT VALVE OF STREPULA CONCENTRICA JONES AND HOLL. $\times 15$. (AFTER JONES AND HOLL.) 36. LEFT VALVE OF STREPULA IRREGULARIS JONES AND HOLL. $\times 15$. (AFTER JONES AND HOLL.) 37. LEFT VALVE OF BEYRICHIA (TETRADELLA?) ERRATICA KRAUSE. (AFTER KRAUSE.) 38. LEFT VALVE OF STREPULA? LINEATA GRANULOSA STEUSLOFF, $\times 20$. (AFTER STEUSLOFF.) SHOWS SIMILAR DEVELOPMENT OF SUPERFICIAL LINEAR CRESTS IN STEUSLOFFIA AND STREPULA. IN TRUE STREPULA THE BEYRICHIAN LOBES ARE NOT CLEARLY DETERMINABLE.

forms. In the *ciliata* section of *Ctenobolbina* the median lobe is undistinguishably merged in the larger posterior bulb which characterizes this section. It began in species like the early Trenton *C. obliqua* Ulrich and the foreign Ordovician *C. oblonga* (*Entomis oblonga* Steusloff), in which this median lobe is merely indicated by the abruptness of the inner slope of the main lobe; and these species seem to have been derived from the previously established *C. subcrassa* section.

In the *subcrassa* section the median lobe is generally distinguishable, appearing as a small or larger node or ridge situated immediately behind the main, median sulcus. Usually the posterior side of the lobe is not sharply defined from the more or less swollen surface behind it. Sometimes, as in *C. umbonata* (*Entomis umbonata* Steusloff) and *C. subcrassa* Ulrich, it forms a small, rounded node on the inner slope of the main posterior bulb. In others (as, for instance, *C. crassa* and *C. fulcrata* Ulrich) it makes a low ridge rising

slightly above the rest of the swollen posterior lobe, and of which it forms the greater part, while in some of the later Silurian species, namely *C. auricularis* (*Bollia auricularis* Jones and Holl), and *C. minor* (*Bollia minor* Krause), it is rendered even more prominent by the almost total obsolescence of the posterior part of the *Ctenobolbina* bulb (the obsolete part corresponds to the posterior lobe of a *Beyrichia*).

Having reached the stages of *C. subcrassa* and *C. fulcrata*, a further discrimination of the median lobe might result in a species like *C. impressa* (*Entomis impressa* Steusloff) and finally in one like *Beyrichia antiqua* of the same author. In this last the median lobe is at least as large as in the average *Beyrichia*, and the species differs from the more usual types of this genus only in the less sharp defini-



FIGS. 39-44.—39. LEFT VALVE OF CTENOBOLBINA UMBONATA (STEUSLOFF). 40. RIGHT VALVE OF CTENOBOLBINA FULCRATA (ULRICH). 41. RIGHT VALVE OF CTENOBOLBINA IMPRESSA (STEUSLOFF). 42. LEFT VALVE OF CTENOBOLBINA SUBCRASSA ULRICH. 43. LEFT VALVE OF BEYRICHIA (STEUSLOFFIA) ANTIQUA (STEUSLOFF), $\times 20$. 44. LEFT VALVE OF BEYRICHIA (STEUSLOFFIA) ACUTA (KRAUSE). (FIGS. 40 AND 42 ARE AFTER ULRICH, 39, 41, AND 43 AFTER STEUSLOFF, AND 44 AFTER KRAUSE. ALL $\times 20$.)

tion of the post-median furrow and in the slight elevation and general lack of definition that pertains to both the anterior and posterior lobes.

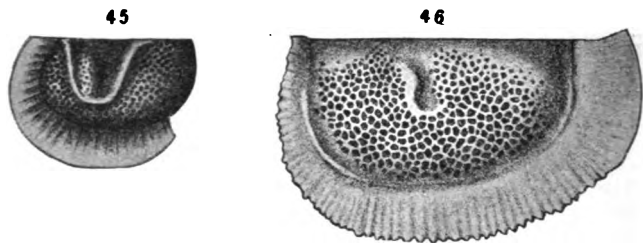
It is probably significant that most of these ribbed or crested species comprising the *B. linnarssoni* group are of Ordovician age, in which rocks *Ctenobolbina* and *Tetradella* are the prevailing genera, and unribbed, true *Beyrichias* almost unknown. The group, therefore, may be viewed as an intermediate stage in the development of at least one of the groups of *Beyrichia* from *Ctenobolbina*.

If accurately figured, Krause's *Strepula reticulata* should perhaps be referred to this group. On account of the proportionately elongate form of its valves and the great width of its marginal frill, the species would stand somewhat apart from the more typical representatives of the group. Because of a similarly fringed and reticulated *Beyrichia* in the Waldron shale of Indiana, it seems just pos-

sible that the figure given by Krause is a little defective at the base of the median and posterior lobes. The Waldron species sometimes even exhibits a suggestion of the V-shaped crest, but, as is shown on Plate XXXVII, the ventral part of the posterior lobe is distinctly contracted, giving an appearance quite different from the same part in Krause's figure of *B. reticulata*, but closely simulating the fringed species of the *B. maccoyiana* group.

As figured, *B. reticulata* appears to be somewhat obscurely lobed, which, with the broad frill, is somewhat suggestive of *Eurychilina*. But it has no sharply defined median pit, and it is thought unlikely that the marginal frill is hollowed out on its inner surface. The median lobe also is too long. It seems probable, therefore, that the general resemblance to *Eurychilina* does not indicate close genetic relations.

The *B. linnarssoni* group has a sufficiently uniform expression to suggest the advisability of its separation as an independent though decidedly synthetic genus. The crested valves recall *Strepsula*, the



FIGS. 45-46.—RIGHT VALVE OF BEYRICHIA RETICULATA (KRAUSE), $\times 20$, AND THE SAME VALVE OF EURYCHILINA RETICULATA ULRICH, $\times 20$ (AFTER ULRICH), SHOWING THE SIMILARITY OF THE TWO FORMS REFERRED TO IN THE TEXT.

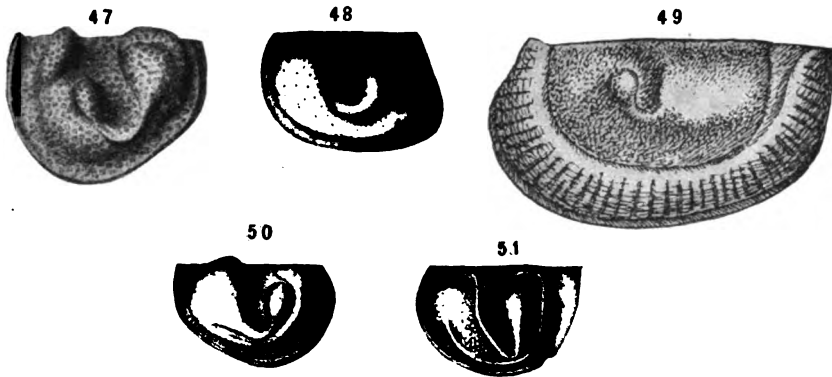
mode of lobation is very much as in the *Beyrichia salteriana* group, and through this resembles on the one hand the typical Beyrichian section of *B. tuberculata* and on the other *Klædenia*. In still another direction, close alliance with *Ctenobolbina*, as above outlined, is established. If *Ctenobolbina* were expanded to take in a part of the group, consistency would demand that species of the *B. salteriana* group be also included. But this would render the boundary between *Ctenobolbina* and *Beyrichia* more artificial than it is desired to make it. Besides, it would split up an apparently very natural association of species.

The group as a whole is undoubtedly more in accord with *Beyrichia* than *Ctenobolbina*, and in the first suggestion of the heterogeneous mass of Beyrichiidae, its species were left with or referred to the restricted genus without much hesitation. However, in the still considerable and variable mass of species having the essential characters of *Beyrichia*, the comparative entity of the *B. linnarssoni* group is lost sight of. In order to secure its deserved recognition without

at the same time completely disassociating it from its most obvious alliance, it is provisionally suggested that the group be distinguished merely subgenerically from *Beyrichia*, and that it be known by the proposed name *Steusloffia*, with *Beyrichia linnarssoni* as the type.

GROUP OF *B. INTERRUPTA*.

Another resemblance that has led to unnatural associations is that borne to *Bollia* by a small group comprising *Beyrichia granulifera*, new name (*Bollia granulosa* Krause, specific name preoccupied under *Beyrichia*), and *B. v-scripta* (Krause), two Ordovician species, *B. damesi* Krause, and *B. interrupta* (Jones and Holl), two Silurian species. In fact, with the exception of *B. damesi*, all of these species were originally referred to *Bollia*, but, as will be clear enough when



FIGS. 47-51.—47. RIGHT VALVE OF *BEYRICHIA INTERRUPTA* (JONES), $\times 20$. 48. LEFT VALVE OF *BEYRICHIA V-SCRIPTA* (KRAUSE), $\times 15$. 49. RIGHT VALVE OF *EURYCHILINA SUBRADIATA* ULRICH, $\times 20$. 50. LEFT VALVE OF *BEYRICHIA CLAVATA* KOLMODIN. 51. LEFT VALVE OF *BEYRICHIA (STEUSLOFFIA) ACUTA* (KRAUSE). (FIG 47 IS AFTER JONES, 48 AFTER KRAUSE, 49 AFTER ULRICH, 50 AFTER KIESOW, AND 51 AFTER KRAUSE.) THE ILLUSTRATIONS SHOW POSSIBLE DERIVATION OF THE *BEYRICHIA INTERRUPTA* GROUP FROM *EURYCHILINA* AND ITS RELATIONS TO THE *BEYRICHIA CLAVATA* GROUP AND TO *STEUSLOFFIA*.

that genus is considered, they do not belong there. The curved ridge in these species seems really to have no greater taxonomic significance than the similar node and ridge often seen in typical *Eurychilina*. On the other hand, the lobation of their valves, though in part obscure, is essentially that of *Beyrichia*, the connection with species of this genus like *B. jonesi* and *B. clavata* being, apparently at least, very clear.

The group suggests passage from *Primitiidae* to *Beyrichia*, but whether this suggestion is based on fact or is merely apparent and thus misleading, can not be decided with the evidence at hand. However, the possibility of species conforming to the generic diagnosis of

Beyrichia having been developed from diverse stocks by convergence in evolution, is worth bearing in mind. In general aspect, and especially in having a well-defined median pit, *B. granulifera* and *B. v-scripta* certainly indicate Primitian ancestry, close affiliations being suggested to both *Primitia* and *Eurychilina* (as, for instance, *E. schmidtii*). However, an analysis of their lobes seems to show more positive alliances on the one hand to the *B. clavata* group of *Beyrichia*, and on the other to the proposed subgenus *Steusloffia*. Perhaps it would be well to institute another subgenus for this group.

Genus KLÆDENIA Jones and Holl.

Klædenia JONES and HOLL, Ann. and Mag. Nat. Hist. (5), XVII, 1886, p. 362.

Klædenia (part) KRAUSE, Zeits. d. d. geol. Gessell., XLI, 1889, p. 21.

Klædenia (part) MILLER, North Amer. Geol. and Pal., First App., 1892, p. 708.

Klædenia (part) KOKEN, Die Leitfossilien, 1896, p. 39, text fig. 26A.

Beyrichia (part) of AUTHORS.

Carapace of moderate size, 1 mm. to 4 or 5 mm. in depth. Valves very nearly equal, the ventral edge of the right valve sometimes very slightly overlapping the edge of the left. Outline oblong, subquadrate to subovate, rarely subtriangular, the hinge line long and straight, the remaining sides more or less curved. Surface of valves strongly convex, especially in the unlobed ventral half; dorsal half with two furrows deep above but growing obsolete before or shortly after crossing half the valve. Anterior furrow deeper and broader than the posterior one and located near the mid-length. Of the three lobes the median is the most constant in size and form. It is generally rounded and somewhat bulbous, more rarely obtusely pointed above, and its diameter usually about one-fifth of the length of the valve. Posterior and anterior lobes sharply defined only along the furrows, the outer parts usually sloping more or less gently to the end rims and below merging into the swollen ventral surface, their dorsal extremities occasionally projecting beyond the horizon line. Posterior lobe varying in width from rather less than to nearly twice the diameter of the median lobe. Anterior lobe constituting the greater part of this half of the valve, sometimes divided so as to form a broad inner lobe and one or two narrower ridges in front. When the anterior lobe is thus prolonged and divided (as, for instance, *K. plicata* Jones), the separating furrows extend entirely across the valve. Ventral pouch (as in *Beyrichia* presumably of female) mostly posterior, merely an extra, obscurely outlined swelling, not globular as in *Beyrichia*. A simple, narrow, flange-like border commonly present but may be wanting. Surface of valves granulose, punctate, reticulate, or without ornament.

Genotype.—*Klædenia wilckensiana* (*Beyrichia wilckensiana* Jones).

LIST OF SPECIES HAVING THE CHARACTERS OF KLÆDENIA AS ABOVE DEFINED.

Klædenia apiculata Jones.

Klædenia barretti^a (*Beyrichia barretti* Weller).

Klædenia centricornis,^a new species.^b

Klædenia concinna (*Beyrichia concinna* Jones and Holl).

Klædenia fimbriata,^a new species.^c

Klædenia granulata^a (*Beyrichia granulata* Hall).

Klædenia initialis^a (*Beyrichia initialis* Ulrich).

Klædenia intermedia (*Beyrichia intermedia* Jones and Holl).

Klædenia intermedia marginata Jones and Holl.

Klædenia jerseyensis^a (*Beyrichia jerseyensis* Weller).

Klædenia kummeli^a (*Beyrichia kummeli* Weller).

Klædenia manliensis^a (*Beyrichia manliensis* Weller).

Klædenia manliensis deckerensis^a (*Beyrichia deckerensis* Weller).

Klædenia marginalis,^a new species.^d

Klædenia montaguensis^a (*Beyrichia montaguensis* Weller).

Klædenia nearpassi^a (*Beyrichia nearpassi* Weller).

Klædenia oculina^a (*Beyrichia oculina* Hall).

Klædenia parasitica^a (*Beyrichia parasitica* Hall).

Klædenia prænuntia,^a new species.^e

Klædenia punctillosa,^a new species.^f

^a American species.

^b The unusual length of the valve, spine-like central node, and coarse pitting are features which will cause the easy identification and differentiation of this species from others of the genus. See Plate XXXVIII, fig. 23.

Formation and locality.—Coeymans limestone, Cumberland, Maryland.

Holotype.—Cat. No. 53305, U.S.N.M.

^c This fine species will be recognized at once by its spinous margin. This spiny frill, together with the reticular surface ornament and general neatness of form, impart a striking elegance to the shell. See Plate XXXVIII, fig. 22.

Formation and locality.—Coeymans limestone, Herkimer County, New York.

Holotype.—Cat. No. 53306, U.S.N.M.

^d This species is similar to *Klædenia manliensis* (Weller), but has a wider margin, is more elongate, and its sulci are much shallower. The surface is smooth, without ornament. See Plate XXXVIII, fig. 16.

Formation and locality.—Helderbergian, Dalhousie, New Brunswick.

Holotype.—Cat. No. 53937, U.S.N.M.

^e The distinctive features of this species are the unusual narrowness of the posterior lobe and the sharp impression yet unusual brevity of the sulci. The smooth surface and obscurely defined marginal rim will likewise assist in the discrimination of the species. See Plate XXXVIII, fig. 15.

Formation and locality.—Ordovician (local bed in upper part of Hermitage formation). Four miles south of Carthage, Tennessee.

Holotype.—Cat. No. 41643, U.S.N.M.

^f This new species is similar to *Klædenia nearpassi* (Weller) and *K. barretti* (Weller) in outline, but its dorsal angle is more nearly rectangular and the marginal rim narrower. The surface is finely punctate. See Plate XXXVIII, fig. 17.

Formation and locality.—Helderbergian, Dalhousie, New Brunswick.

Holotype.—Cat. No. 53938, U.S.N.M.

Klædenia retifera,^a new species.^b

Klædenia scotica (*Beyrichia klædeni*, var. *scotica* Jones and Holl.)

Klædenia simplex^a Jones.

Klædenia smocki^a (*Beyrichia smocki* Weller).

Klædenia sussacensis^a (*Beyrichia sussacensis* Weller).

Klædenia tuberculata (*Beyrichia tuberculata* Salter).

Klædenia wallpackensis^a (*Beyrichia wallpackensis* Weller).

Klædenia wilckensiana (*Beyrichia wilckensiana* Jones).

Klædenia wilckensiana plicata (*Beyrichia wilckenstana plicata* Jones).

Of the above species, *K. initialis* and *K. prænuntia* are middle Ordovician and *K. simplex* late Devonian. All the others are of Silurian, mainly late Silurian, age.

It will be seen from this list of species that *Klædenia*, as here defined, includes only six of the twelve species and varieties which have been referred to it. Most of the others constitute a distinguishable group of which *K. pennsylvanica* Jones is a good example, and which it is proposed to separate as a new genus under the name *Klædenella*. The new genus, as will be more fully set forth on a following page, differs from true *Klædenia*, as understood by the writers, chiefly in the more cylindrical form of its shells and the greater inequality of its valves. In both of these respects, typical *Klædenia* is essentially the same as *Beyrichia*, the differences between the two lying in the relative convexity and lobation of the valves.

In *Beyrichia* the valves are depressed convex, the three lobes are represented by sharply defined ridges or elevations which rise abruptly above the flattened floor of the valves. The ridges are separated by deep, vertical furrows, which, though varying in width, are yet very constant in their length. As a rule, the posterior furrow extends across the valve to the ventral rim. The anterior furrow commonly is limited below by the ventral junction of the anterior and median lobes, but when the latter is isolated it passes around the lower side of the median lobe and merges with the posterior furrow.

In *Klædenia* the main furrows never extend across the valves, but are confined to its dorsal half. They mark off a rather large submedian node and often converge beneath so as to isolate it. The anterior and posterior lobes are broad and never ridge-like, but, as a rule, form part of the general convexity of the valve. In fact, the majority of the species might be described as approximately uniformly convex save for the short furrows inclosing the median node.

^a American species.

^b The surface ornament, practically obsolete marginal rim, the small spine at posterior extremity of hinge, and the unusually slight depth of the sulci are characters which will distinguish this species. See Plate XXXVIII, fig. 18.

Formation and locality.—Helderbergian, Dalhousie, New Brunswick.

Holotype.—Cat. No. 53939, U.S.N.M.

The relations of the genus to the group of *Beyrichia salteriana*, which section of *Beyrichia* includes the species most like *Klædenia*, have been discussed on a preceding page.

Klædenia may have been evolved through several rather widely different ways. First, it may have been derived from the *salteriana* group of *Beyrichia* by the ventral coalescence of the three lobes. Though possible, even reasonable, the known species afford no satisfactory evidence of such an alliance. In the absence of intermediate stages, the evidence must be admitted as wholly negative, if not positively opposed to this view. Considering that the *salteriana* group of *Beyrichia* is Silurian, and that *Klædenia*-like ostracoda began already in middle Ordovician time, it is clear that only a part of the genus could have been descended from *Beyrichia*.

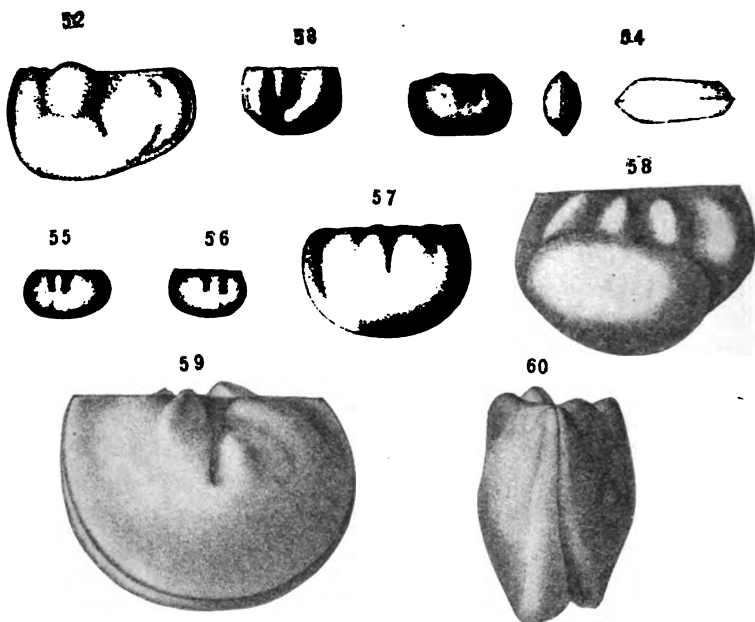
According to the second view, *Klædenia* was derived from some unisulcate Primitian stock by the segregation and enlargement of the post-median node. Suggestive resemblances may be noted on comparison with the Ordovician *Primitia tumidula*, *P. cincinnatiensis*, *Eurychilina reticulata*, and *E.?* *subæquata*. Regarding the two valves of *P. tumidula* figured by Ulrich^a as right valves, and comparing them with the right valve of *Klædenia initialis* (*Beyrichia initialis* Ulrich) figured on the same plate, the possible derivation from *Primitia* is clearly indicated by correlation of the nodes and furrows. It should be borne in mind, however, that this comparison merely indicates the *kind* of steps by which passage from *Primitia* to *Klædenia* may have been effected, and not the links themselves, because *K. initialis* is older than either of the two *Primitias* mentioned.

Still other derivations are suggested by the new Ordovician species, *K. prænuntia*. This is a larger shell than any *Primitia* and has the median lobe too well separated to recall that genus. Except for the much sharper definition of the *Klædenia* characteristics, this species resembles leperditellæ like *L. germana* and *L.?* *dorsicornis*. But it recalls even more *Drepanella elongata*, which differs in little that may be called essential except that it has the sickle-shaped ridge of *Drepanella*. This ridge is weaker in *D. elongata* than usual, and it is really conceivable that it might have become obsolete early in the descendants of this species, and thus give origin to a stage that, with our present limited knowledge, must be referred to *Klædenia*.

These diverse, yet all reasonably possible, derivations of *Klædenia* illustrate the extreme difficulties encountered in determining the genetic relations of the major groups of the family Beyrichiidae. Though inclined to favor the view that the majority of the species referred to *Klædenia* were evolved out of *Primitia*, it must be admitted that the evidence is far from conclusive.

^a Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, pl. XLIII, figs. 62-65.

The genus *Kyammodes* Jones, founded on a British Devonian species, but thought to include also a few Silurian forms (as, for instance, *Klædenia kiesowi* Krause), doubtless is closely allied to and probably evolved out of typical *Klædenia*. Though distinguished chiefly by the much greater inequality of its valves, the thick ventral edge of the right overlapping the smaller left valve, there are some peculiar differences in lobation also. In all the species there is a deep median furrow that, however, dies out before reaching the middle of the valve. In *Kyammodes kiesowi* (*Klædenia kiesowi* Krause) the parts



FIGS. 52-60.—52, 53. RIGHT VALVE OF *KLÆDENIA WILCKENSIANA* (JONES), $\times 8$ (FEMALE INDIVIDUAL), AND *BEYRICHIA SALTERIANA* JONES, $\times 10$, RESPECTIVELY, SHOWING THE RELATION OF *KLÆDENIA* TO THE *B. SALTERIANA* GROUP. (AFTER JONES AND REUTER.) 54. LEFT SIDE, END, AND VENTRAL VIEWS OF COMPLETE CARAPACE OF *KLÆDENELLA PENNSYLVANICA* (JONES), $\times 15$. (COPIED FROM JONES.) 55, 56. RIGHT AND LEFT VALVES OF *KLÆDENIA NEARPASSI* (WELLER), $\times 6$. (AFTER WELLER.) 57, 58. LEFT AND RIGHT VALVES, THE LATTER A FEMALE FORM, OF *KYAMMODES KIESOWI* (KRAUSE), $\times 10$. (AFTER KRAUSE.) 59, 60. LEFT VALVE AND ANTERIOR VIEW OF COMPLETE CARAPACE OF *KYAMMODES WHIDBORNEI* JONES, $\times 20$. (AFTER JONES.) THE SIMILARITY OF *KLÆDENIA*, *KLÆDENELLA*, *KYAMMODES*, AND THE *BEYRICHIA SALTERIANA* GROUP ARE SHOWN IN THE ABOVE FIGURES.

of the valve are arranged almost regularly bilaterally with respect to this furrow, which separates two subequal, low nodes, each taking up about one-fifth the total length of the valve. The outer limits of these nodes are defined by shallower converging furrows, which in turn set off another matching pair of similarly curving low ridges. In *K. whidbornei*, the type of the genus, the lobes are both less regular and less constant in their development, the posterior median lobe, which corresponds to the median lobe of *Klædenia*, being especially variable. As a rule it is smaller and set farther down than the antero-

median one, and, furthermore, tends to merge with the post-dorsal node.

The type of the genus *Klædenia*, *K. wilckensiana*, occupies an intermediate position between two sections into which the genus is divisible. One of these sections, the smaller, includes, with the genotype, most of the European species, while all the known American forms fall into the second. The first section is characterized by a tendency to produce and to attenuate the anterior extremity and to develop on this part one or two accessory furrows. In consequence the outline of the valves is more or less triangular and comparatively elongate. In the American section of the genus the valves are usually shorter, the ends approximately equal and the anterior one without distinct furrows.

Of American species, *K. oculina* (Hall) and *K. notata* (Hall) probably are to be regarded as nearest to *K. wilckensiana*. It is certain at least that they are congeneric, and it seems no less a fact that these species belong to the same genus as those constituting the prevailing American type of Beyrichiidæ found in the late Silurian Manlius and Coeymans, members of Hall's Lower Helderberg group. The writers therefore feel little hesitancy in revising and restricting the genus as indicated above. The elimination of the *K. pennsylvanica* group is the most important departure from Jones's later conception of *Klædenia*. Another is the inclusion of certain species, like *K. tuberculata* (Salter), which he had left with *Beyrichia*, indeed, in the case mentioned, as a variety of *B. klædeni*. Speaking of *K. tuberculata*, it is worth noting that this is one of the very few European Beyrichiidæ that is represented in America by a form so nearly like Scandinavian specimens that a specific distinction is scarcely justified. Hall called the American variety *Beyrichia granulata*.

Except the two Ordovician species, *K. prænuntia*, new species, and *K. initialis*, and the Chemung species, *K. simplex*, all of which, though doubtless possessing the essential features of the genus, are yet referred here with some misgivings, the genus *Klædenia* is confined to Silurian rocks. In its typical expression, indeed, the genus might be regarded as one of the most characteristic fossils of this system. In America there are numerous, in part undescribed species. By far the greater number of these are found in the upper parts of the Silurian and principally in the Manlius and Coeymans limestones. So far none has been seen in the overlying New Scotland formation. It is interesting and important to note further that all the known species are confined to Appalachian and more eastern Atlantic provinces, the genus apparently having failed to gain a foothold in the interior Ohioan Province.

The new species figured on Plate XXXVIII are only a part of those determined during the course of the present studies.

Genus TETRADELLA Ulrich.

Tetradella ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1890, pp. 112-114.

Tetradella MILLER, North Amer. Geol. and Pal., First App., 1892, p. 711.

Tetradella ULRICH, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 677.

Beyrichia (part) of AUTHORS.

Based on *Tetradella quadrilirata*, the genotype, and drawn up so as to include the subjoined list of unquestioned species, this genus may be characterized as follows:

Carapace small, 1 mm. to 2 mm. long, equivalved, never tumid, somewhat oblong, varying from subquadrate to subovate, with the hinge line straight. Valves depressed-convex, deeply trisulcate, the furrows separating four more or less sharply elevated ridges. As a rule the ridges connect ventrally, but are quite distinct at their dorsal extremities, the result being a semielliptical submarginal ridge with two simple or double, equal or unequal, and less curved ridges within the inclosed space. These inner ridges commonly unite with the ventral part of the marginal ridge and extend upward from it toward the dorsal edge, the posterior one often failing to reach it. Free margins usually with a simple flattened border, which in certain cases extends beyond and conceals thickened contact edges. Surface of valves usually smooth, occasionally minutely granose.

All of the species of *Tetradella* and of the new subgenus *Kiesowia*, a list of which follows, are derived from Ordovician strata.

LIST OF SPECIES OF TETRADELLA.

Tetradella ? *affinis* (*Beyrichia affinis* Jones).

Tetradella bohémica (*Beyrichia bohémica* Barrande MSS. Jones).

Tetradella bussacensis (*Beyrichia bussacensis* Jones).

Tetradella carinata (*Beyrichia carinata* Krause).

Tetradella complicata (*Beyrichia complicata* Salter).

Tetradella complicata decorata (*Beyrichia complicata*, var. *decorata* Jones).

Tetradella ? *digitata* Krause (*Beyrichia digitata* Krause).

Tetradella ? *digitata separata* (*Beyrichia digitata*, var. *separata* Steudloff).

Tetradella (*Kiesowia*) *dissecta* (*Beyrichia dissecta* Krause).

Tetradella ? *erratica* (*Beyrichia erratica* Krause).

Tetradella harpa (*Beyrichia harpa* Krause).

Tetradella ? *lacunata* (*Beyrichia lacunata* Jones and Holl).

Tetradella lunatifera ^a (*Strepsula lunatifera* Ulrich).

Tetradella (*Kiesowia*) *mamillosa* (*Beyrichia mamillosa* Krause).

Tetradella marchica (*Beyrichia marchica* Krause).

Tetradella marchica angustata (*Beyrichia marchica*, var. *angustata* Krause).

Tetradella marchica lata (*Beyrichia marchica*, var. *lata* Krause).

Tetradella palmata (*Beyrichia palmata* Krause).

^a American species.

Tetradella quadrilirata^a (*Beyrichia quadrilirata* Hall and Whitfield).

Tetradella (Kiesowia) radians (*Beyrichia radians* Krause).

Tetradella ribeiriana (*Beyrichia ribeiriana* Jones).

Tetradella simplex^a (*Tetradella quadrilirata* var. *simplex* Ulrich).

Tetradella subquadrans^a Ulrich.

In the original description of the genus^b the species subsequently distinguished as *Ceratopsis*^c were included. In 1889^d the typical species was erroneously referred to *Strepula* Jones and Holl. In 1894,^e when the revised description of *Tetradella* was published, certain European species were referred to the genus, which it is now thought advisable to view as doubtful or to place elsewhere. Thus, *T. signata* Krause, as mentioned on page 295, is now referred to *Steusloffia*, a proposed subgenus of *Beyrichia*. *T. (Beyrichia) erratica* Krause may belong to the same subgenus, but it is preferred to regard it provisionally as questionable, because, with the evidence available to the writers, it is impossible to decide that it is not a *Strepula* rather than a *Tetradella* or a *Steusloffia*. *T. (Beyrichia) lacunata* Jones may be a degenerated species of the genus, but in the absence of satisfactory specimens it should be placed as doubtful. *T. (Beyrichia) affinis* Jones also is doubtful, and the same is true of *T. (Beyrichia) digitata* Krause. Of the species there designated as "somewhat doubtful upper Silurian representatives," *B. nodulosa* is returned to *Beyrichia*, but *B. dissecta* Krause, *B. radians* Kiesow, and *B. mamilliosa* Krause must be removed or continue to be regarded as questionable. The dissection of the lobes in the latter two is somewhat similar to what occurs in *Beyrichia* of the group of *B. tuberculata* (see page 289). Critically compared, however, the breaking up of the lobes is not exactly the same. No *Tetradella* could be dissected so as to look like *B. tuberculata* or any of its immediate allies; but if the vertical part of the ridges of, say, *Tetradella subquadrata*, were divided transversely and the furrows were extended ventrally through the marginal ridge, the result would be, in every essential respect, precisely as in *B. dissecta*. The size of the valves also accords much better with the average for *Tetradella* than for *Beyrichia*. Under the circumstances, a separation from both *Beyrichia* and *Tetradella* is suggested, but should it be decided, as the writers believe, that the two species were derived from *Tetradella*, the demands of classification might very well be satisfied by subgeneric discrimination. The name *Kiesowia* is proposed, with *Beyrichia dissecta* Krause as the type of the new genus or subgenus.

^a American species.

^b Jour. Cincinnati Soc. Nat. Hist., XIII, 1890, p. 112.

^c Ulrich, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 675.

^d Ulrich, Geol. Surv. Canada, Cont. Micro-Pal., Pt. 2, 1889, p. 54.

^e Ulrich, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 677.

Genus CERATOPSIS Ulrich.

Ceratella ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1890, p. 113 (not established).

Ceratopsis ULRICH, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 675.

Beyrichia (part) of AUTHORS.

Carapace essentially as in *Tetradella* except that the post-dorsal end of the marginal ridge is raised into a strong, spine-like, or a mushroom-shaped process, which is commonly beaded or fimbriated along one edge or around the flattened top. Free edges of carapace blunt, the contact line between the two valves concealed by well-developed false borders.

Genotype.—*Ceratopsis chambersi* (*Beyrichia chambersi* Miller).

This genus stands to-day in essentially the same position given it in the original definition. The species referred to it then are still retained, and few new species or varieties of the genus have been discovered in the past fourteen years. Among the specimens then referred to the genotype several minor varieties might have been distinguished, but the propriety of doing so was not appreciated at the time. At least one, and probably two, of these varieties seem to be confined to different stratigraphic horizons. Their discrimination, therefore, in a subordinate degree might be desirable on this account alone. However, as the prime object of this paper is to discuss generic rather than specific and minor variations, it is thought advisable to defer such matters to a time when it will be possible to treat the subject monographically.

In addition to *C. chambersi*, the genus includes *C. robusta* Ulrich, *C. intermedia* Ulrich, *C. oculifera* Hall, all American upper Ordovician species, and *C. hastata* (*Beyrichia hastata* Barrande), a Bohemian species of similar age. *Beyrichia rostrata* Krause, from Ordovician drift in northern Germany, seems referable to *Ceratopsis* rather than *Tetradella*. The same is to be said of *Beyrichia quadrifida*, described by Jones as from the "Trenton" at Lorette Falls, Canada. In the figured specimen of the latter the horn is evidently broken away. In the former, providing Krause's figures represent the species fully and accurately, the horn is not so well developed as in the Cincinnati species. Assuming that the last two are correctly understood, then the genus, as at present known, comprises seven species, ranging in time from about Black River to the close of the Ordovician. Apparently the stock became extinct with the close of this period.

Genus CTENOBOLBINA Ulrich.

Ctenobolbina ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1890, p. 108.

Ctenobolbina MILLER, North Amer. Geol. and Pal., First App., 1892, p. 706.

Bollia (part) KRAUSE, Zeits. d. d. geol. Gesell., XLIV, 1892, p. 392.

Entomis (part) STEUSLOFF, Zeits. d. d. geol. Gesell., XLVI, 1894, p. 780.

Ctenobolbina ULRICH, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 673.

Ctenobolbina GRABAU, Bull. Buffalo Soc. Nat. Sci., VI, 1899, p. 309.

Ctenobolbina ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIX, 1900, p. 180.

Beyrichia (part) of AUTHORS.

Carapace small, usually less than 2 mm. in length, subquadrate or subovate in outline, the hinge line long and straight; posterior two-fifths more or less decidedly bulbous or subglobular in the typical section of the genus, but in the *C. subcrassa* section the corresponding parts of the carapace are smaller and usually of lesser thickness than certain portions in front of it. In the latter section a small node (the homologue of the median lobe of *Beyrichia*) is sometimes distinguishable on the inner slope of the posterior lobe. One deep, long, narrow, generally curved and more or less oblique sulcus extends from the middle of the dorsal edge toward the post-ventral angle, occasionally reaching the border. Area in front of median sulcus either simply convex or divided by a shallower furrow usually paralleling the main sulcus. Valves equal, the free edges thick, the contact margins generally concealed, partly or wholly, in a lateral view, by a variously modified overhanging border. Surface granulose, smooth, or punctate.

Genotype.—*Ctenobolbina ciliata* (*Beyrichia ciliata* Emmons).

Since 1890, when this genus was first described, Ulrich has on two occasions (both cited above) added to the list of species originally referred to the genus. Recent studies of the family have convinced the writers that a good part of these later additions represents, as indicated on page 295, atavistic Devonian stages in the development and decadence of the predominating Silurian phase of the family. Admitting this as probably true, it is thought desirable and of distinct advantage in classification to remove these species from *Ctenobolbina* and to refer them, together with a few species hitherto placed with *Beyrichia* and *Bollia*, to a new genus for which the name *Hollina* is proposed on a following page.

Even after the elimination of this peculiar Devonian group, the remaining species fall into two easily distinguishable subgenera or sections of the genus. The first of these two groups includes *C. ciliata* and its immediate Ordovician allies—all of them with a granulose surface ornament—one early Trenton, one Silurian species with finely reticulate surface, one Helderbergian, and one middle Devonian papillose species. This section is characterized by the

thick, bulb-like form of the posterior lobe, which single swelling comprises both the median and the posterior lobe of a true *Beyrichia*, and by its surface ornament. The second group consists of species without surface ornamentation and whose average size is inferior to that of the first group. The posterior lobe is smaller and commonly exhibits a tendency to segregate a small node or undefined swelling on its inner slope that doubtless represents the larger and more definitely separated median lobe of *Beyrichia*. So far this section is known by seven Ordovician species, one Silurian, one Devonian, and one early Mississippian species. It seems probable that the two Ordovician forms described by Krause as *Bollia minor* and *Bollia major*^a are also referable to this section. They are most certainly not true *Bollias*.

As now restricted and defined, *Ctenobolbina* includes the following species:

GROUP OF CTENOBOLBINA CILIATA.

ORDOVICIAN SPECIES.

- Ctenobolbina alata*^b Ulrich.
- Ctenobolbina biapinosa*^b Ulrich.
- Ctenobolbina ciliata*^b (*Beyrichia ciliata* Emmons).
- Ctenobolbina curta*^b (*Ctenobolbina ciliata*, var. *curta* Ulrich).
- Ctenobolbina duryi*^b (*Beyrichia duryi* Miller).
- Ctenobolbina emaciata*^b (*Ctenobolbina ciliata*, var. *emaciata* Ulrich).
- Ctenobolbina guillieri* (*Beyrichia guillieri* Tromelin).
- Ctenobolbina hammelli*^b (*Beyrichia hammelli* Miller and Faber).
- Ctenobolbina obliqua*^b Ulrich.
- Ctenobolbina oblonga* (*Entomis oblonga* Steusloff).

SILURIAN SPECIES.

- Ctenobolbina granosa*^b Ulrich.
- Ctenobolbina punctata*^b Ulrich.

DEVONIAN SPECIES.

- Ctenobolbina papillosa*^b Ulrich.

GROUP OF CTENOBOLBINA SUBCRASSA.

ORDOVICIAN SPECIES.

- Ctenobolbina crassa*^b Ulrich.
- Ctenobolbina fulcrata*^b Ulrich.
- Ctenobolbina impressa* (*Entomis impressa* Steusloff).
- Ctenobolbina major* (*Bollia major* Krause).
- Ctenobolbina minor* (*Bollia minor* Krause).
- Ctenobolbina subcrassa*^b Ulrich.
- Ctenobolbina umbonata*^b (*Entomis umbonata* Steusloff).

^a Zeits. d. d. geol. Gesell., XLIV, 1892, pp. 391, 392, pl. xxi, figs. 15, 18.

^b American species.

SILURIAN SPECIES.

Ctenobolbina auricularis (*Bollia auricularis* Jones).

DEVONIAN SPECIES.

Ctenobolbina minima ^a Ulrich.

MISSISSIPPIAN SPECIES.

Ctenobolbina loculata ^a Ulrich.

Krause ^b and Steusloff ^c have described and referred a number of unsulcate Ordovician species to *Entomis*. This arrangement of the species is probably incorrect, the present writers doubting even that the typical Entomidæ are Ostracoda at all. Krause's and Steusloff's entomids, on the contrary, seem to be closely allied to *Ctenobolbina*, and, in part at least, congeneric with species referred to this genus. Others like Krause's *E. sigma* and *E. obliqua* are so completely bilobed as to suggest *Dilobella*. Pending an opportunity to study specimens of all these species, those not elsewhere referred in this work may be provisionally left where their authors placed them.

As stated on page 290, *Ctenobolbina tumida* Ulrich ^a (see fig. 24, p. 292) is now thought to be a peculiar *Beyrichia* and to have no very intimate relations to the typical species of *Ctenobolbina*. Indeed, the bulbous end of the carapace in *B. tumida* is regarded as anterior, whereas in *C. ciliata* the thicker end is posterior. Hence, if the species is allied to *Ctenobolbina* at all, it must be to the *C. subcrassa* section and not to the typical section of the genus.

The genetic alliance of *Ctenobolbina* to *Beyrichia* (more especially to the subgenus *Steusloffia*) has been discussed on pages 296 to 299.

Genus DREPANELLA Ulrich.

Depranella ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1890, pp. 117, 118.

Depranella MILLER, North Amer. Geol. and Pal., First App., 1892, p. 707.

Drepanella (part) ULRICH, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 670.

Carapace equivalves, usually about 2.5 mm. long, compressed convex, somewhat oblong, subquadrate to subelliptical in outline; dorsal edge straight, ventral side gently convex, ends subequal, the post-dorsal angle sharper than the anterior. A constant sickle-shaped, sharply defined ridge runs nearly parallel with and generally not far within the posterior and ventral edges of the valves. Central and

^a American species.

^b Zeits. d. d. geol. Gesell., XLIV, 1892, pp. 383-399; XLVIII, 1896, p. 935.

^c Idem, XLVI, 1894, p. 777.

^d Jour. Cincinnati Soc. Nat. Hist., XIII, 1890, p. 111, pl. VII, figs. 5a, 5b.

dorsal regions with two to seven nodes, the larger numbers resulting through dissection of the primary two. When only two, they may form a loop by union of their ventral parts. Surface smooth or coarsely reticulated.

Genotype.—*Drepanella crassinoda* Ulrich. Other species referred here, all of Ordovician age, are: *D. ampla* Ulrich, *D. bigeneris* Ulrich, *D. crassinoda nitida* Ulrich, *D. elongata* Ulrich, *D. macra* Ulrich, *D. richardsoni* (*Beyrichia richardsoni* Miller) and *D. richardsoni canadensis* Ulrich.

This apparently wholly American genus is remarkable for the extreme variability of the nodes within the central area of the valves. The binodose *D. ampla* probably represents the most simple type. From this we pass to *D. elongata*, with its ventrally fuller valves and Klødenia-like reduction and disposition of the nodes. There is a depression or sulcus between the nodes in this species. A similar depression of the surface outside of the nodes, without a reduction in altitude of the nodes and the lower boundary of the median sulcus, would result in a form essentially like *D. bigeneris*, which is strikingly like a *Bollia*. In *D. macra*, *D. crassinoda*, and *D. nitida* the nodes range in number from three in the first to seven in the last. A comparison of the nodes of these three species established beyond question that the larger numbers are produced by dissection. Indeed, the seven nodes of *D. nitida* are all indicated by corresponding wholly or partially separated nodes in *D. crassinoda*, and the corresponding parts are no less easily recognized in *D. macra*.

The only constant features of *Drepanella* are the sickle-shaped submarginal ridge, and, within reasonable bounds, the size of the carapace. In other respects the species are sometimes highly suggestive of in part probably very distinct contemporary and later genera. Thus, as stated on page 303, *D. elongata* might be classed as a *Klædenia* if it had not the characteristic, submarginal ridge, while it is really difficult to point out sufficient reasons for excluding *D. bigeneris* from *Bollia*. But *Drepanella* is an old genus—probably the oldest of the true rigid Beyrichiidae—having been already well established in the Stones River epoch. These diverse resemblances may, therefore, be explained as synthetic vacillations of an ancient type prior to the fixation of generic characters marking later developmental stages within the family. The sickle-shaped ridge, however, was a fixed character and doubtless left its imprint in the history of the family. It is, therefore, not surprising that in the decadence of the main Silurian genus *Beyrichia* this ridge is again occasionally recognized. It is well shown, for instance, in the peculiar Devonian descendant of *Beyrichia*, *Hollina kolmodini* (Jones).

The probable relations of *Drepanella* to *Beyrichia*, especially to the *tuberculata* and the *clarata* sections, have been sufficiently dis-

cussed on pages 289 and 294. It is a remarkable fact that these two alliances are more obvious and apparently more intimate than are those between *Drepanella* and such nearly equally old genera as *Ctenobolbina* and *Tetradella*. There is so little evidence of transition between them that derivation of either of the latter from the first, or of the first from either of the latter, seems out of the question. Though it is highly probable that all three were derived out of the same stock—presumably *Primitia*—it seems certain that the departures from that primitive line were entirely independent and in all cases rapid. Indeed, *Primitia* itself, which contains the oldest of the distinctly furrowed Ostracoda, does not, geologically speaking, greatly antedate *Drepanella*. The Cambrian seems to contain no Ostracoda at all,^a the oldest known representatives of the class being Leperditiidæ, found in rocks of Beekmantown age. The Primitiidae and Beyrichiidae did not appear till post-Beekmantown.

The species described in 1894 by Ulrich as *Drepanella bilateralis*^b is so peculiar that it seems unwise to continue listing it as a species of this genus. Though exhibiting a general resemblance to *D. crassinoda*, it seems on closer comparison that the surface lobation is really very different. In the first place, the marginal ridge is developed only along the ventral border, terminating abruptly on both sides, when it begins to turn up on the ends. Next the nodes above the ridge do not correlate satisfactorily with those of any of the other species. There is a bilateral symmetry in their form and arrangement with respect to the small mid-dorsal node that can not be duplicated in typical *Drepanella*, nor readily explained. The explanations occurring to the writers entail departures from that generic type of such importance that the removal of the species from *Drepanella* seems imperative. If the posterior node is assumed to be in part made up of the post-dorsal portion of the marginal ridge, then its inner part must represent the lower two-thirds of the trinode post-median ridge of *D. crassinoda* and the mid-dorsal node the upper third of that ridge. According to another interpretation the mid-dorsal node of *D. bilateralis* would correspond to the dorsal part of the antero-median node of *D. crassinoda* and the main but antero-median node, together with the crescentic ridge beneath it and the small antero-dorsal node in the latter. In either case it would mean that the mid-dorsal node occupies a different position from the corresponding part of typical *Drepanella*; also modification of the posterior lobes scarcely compatible with a strict conception of

^a A comprehensive study of the supposed Cambrian Ostracoda recently completed has led to the conviction that these are Phyllocarida and not Ostracoda.

^b Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 671, pl. XLVI, figs. 35–38.

Drepanella. Under the circumstances the writers feel justified in proposing a new genus, with the following brief diagnosis.

Genus SCOFIELDIA, new.

Drepanella (part) ULRICH, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 670.

Carapace 2 mm. to 3 mm. in length, oblong, subquadrate, compressed; surface of valves broken up into ridges and nodes arranged bilaterally with respect to a small node situated close to the middle of the straight hinge line; on either side a large, irregularly triangular, ridged node, and along the ventral edge a thick, sharply elevated, bar-like ridge.

Genotype.—*Scofieldia bilateralis* (*Drepanella bilateralis* Ulrich).

The generic name is given in remembrance of Mr. Wilbur H. Scofield, with whom the senior author was pleasantly associated in the study of the Ordovician Gastropoda of Minnesota.

Genus TREPOSELLA, new.

Beyrichia (part) ULRICH, Journ. Cincinnati Soc. Nat. Hist., XIII, 1891, p. 190.

Carapace small, about 1 mm. in length, semiovate or subquadrate, the hinge long and straight, the other margins curved and supplied with a radially striated frill. Ventral part of valves swollen, the fullness forming a low, not sharply defined longitudinal ridge. Just above this, two unequal nodes, the smaller being of hemispheric form and located just behind the center of the valve. The larger node is somewhat balloon-shaped, situated in front of the middle, connected to the ventral ridge by a narrow neck, from which it extends upward to or slightly beyond the dorsal edge. Between the two nodes, a narrow, sharply excavated sulcus, terminating below in a pit. Female (?) provided with a sharply defined, egg-shaped, ventral pouch, located practically midway between the ends.

Genotype.—*Treposella lyoni* (*Beyrichia lyoni* Ulrich).

This genus is proposed for the reception of what is supposed to be an important link in the evolution of *Hollina* from *Beyrichia*. The female is still provided with a ventral pouch, but it is essentially median in position, while in all true *Beyrichia* it is placed well behind the mid-length. The anterior lobe also is essentially as in *Beyrichia*, but the indefinite ventral swelling is suggestive of *Kladenia* rather than *Beyrichia*. Compared further with *Beyrichia*, the entire obsolescence of the posterior ridge of that genus in *Treposella* is perhaps the most striking difference. The presence of a sharply defined median pit, as in *Eurychilina* and other Primitiidae, is probably a reversion to ancestral characteristics.

Except the ventral pouch, all the above-mentioned departures from the typical Silurian *Beyrichia* are toward the new Devonian and Carboniferous genus *Hollina*. Indeed, were it not that *T. lyoni* still possesses the Beyrichian ventral pouch, the writers would undoubtedly have referred the species to *Hollina*. But, having a pouch, and being also in other features nearer *Beyrichia* than is any one of the species of *Hollina*, the intermediate position of *T. lyoni* seems assured. As its inclusion in either of these genera would introduce undesirable elements of uncertainty in their respective diagnoses, it has been thought advisable to give it and any other similar species that may be discovered an independent position.

Genus HOLLINA, new.

Ctenobolbina (part) ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1891, p. 187; XIX, 1900, p. 182.

Beyrichia (part) JONES, Quart. Jour. Geol. Soc. London, XLVI, 1890, p. 538.—ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1891, p. 189.

Bollia (part) ULRICH, Jour. Cincinnati Soc. Nat. Hist., XIII, 1891, p. 205.

Carapace elongate, produced and tapering somewhat anteriorly, essentially equivalved. Valves provided with a marginal frill, concave on the inner side, overhanging the contact edge, often wanting at the anterior end. Except for two constant rounded nodes, the lobation of the surface varies greatly. One of the constant nodes is situated close to and partly in front of the middle of the hinge line; the other, usually the smaller, is placed lower and more or less behind the center of the valve. Occasionally the hollow between these two nodes is excavated. In most species there is a continuous or broken ridge in the ventral part; in one (*H. kolmodini*) this ridge continues up the hinder end to the dorsal angle, in others (*H. insolens* and *H. tricollina*) the post-dorsal extremity remains prominent and forms a rounded node, the remainder of the ridge being dissected and tending to obsolescence; in two other species (*H. granifera* and *H. antespinoza*) the ventral ridge joins the two constant nodes, the result being a loop as in *Bollia*. Finally, in a later stage (as, for instance, *H. radiata*) the ventral ridge is obsolete and only two rounded nodes remain. Occasionally an extra node is developed near the anterior margin. A ventral pouch, as in *Beyrichia*, has not been observed.

Genotype.—*Hollina insolens* (*Ctenobolbina insolens* Ulrich). Seven other middle Devonian species and four Carboniferous species are referred here as follows: *H. antespinoza*, *H. armata*, *H. cavimarginata*, *H. informis*, *H. spiculosa*, all described by Ulrich as species of *Ctenobolbina*, and *H. kolmodini* and *H. tricollina*, originally referred to *Beyrichia*, the first by Jones, the second by Ulrich. The Carboniferous species are *H. granifera*, a Spergen species described

as a *Bollia* by Ulrich, *H. radiata* (*Beyrichia radiata* Jones and Kirkby), variety *cestriensis* Ulrich, *H. longispina* (*Beyrichia longispina* Jones and Kirkby), and *H. emaciata* (*Beyrichia ? emaciata* Ulrich and Bassler).

Comparison of the figures on Plate XLII gives a good idea of the unusual range of variability of the species associated in this new genus. On closer study, however, strong elements of similarity will be noted running through the whole assemblage, the observer being finally convinced of the essential naturalness of the association. It is not contended that the group is natural in the sense of being composed of species descended from a single ancestor. On the contrary, it is believed they were derived from perhaps several preceding species of *Beyrichia* and possibly *Utenobolbina*, and that the singularities resulted through atavistic tendencies developed in the Devonian decadence of the Silurian *Beyrichiidae*.

The Devonian species of the genus may be regarded as vacillating intermediate stages between the trilobate Silurian *Beyrichia* and the final, again long-lived, simply binodate Carboniferous phase of the new genus, namely, the small group of species of which *H. radiata* (Jones and Kirkby) is a typical example. Whereas most of the Devonian species occur at the Falls of the Ohio in a thin bed thought to be of Onondaga age, indicating rapid evolution, *H. radiata* ranges with very slight change from the Chester to near the close of the Pennsylvanian.

Compared with true *Beyrichia*, which has constantly three vertically elongated lobes, the new genus *Hollina* is distinguished (1) by the progressive obsolescence of the posterior lobe, (2) by the rounded form of the median and anterior nodes or lobes, (3) by the restriction of these nodes to the dorsal half of the valve, (4) by the relative fullness of the ventral parts (agreeing in this respect with *Klædenia*), and (5) by the constant development of an anteriorly incomplete marginal frill. A probable sixth difference is indicated by the apparent absence of a ventral pouch.

The fullness of the ventral region, also the rounded form of the median (posterior) node suggests even closer alliances with *Klædenia*, but the rather obvious relations of *Hollina* to *Trepostella lyoni* and the probable derivation of that species from *Beyrichia* tends to negative this suggestion. The Devonian species would never cause one to think of *Klædenia*. It is only the more simple *H. radiata* group that might recall that Silurian genus. But these even will be distinguished at once by the anterior node, the like of which never occurs in *Klædenia*.

In a former paper,^a the writers mention the possible desirability of including *B. radiata* and its immediate allies in *Ulrichia*. It is

^a Proc. U. S. Nat. Mus., XXX, 1906, p. 152.

now quite clear that such a course would be unwarrantable. Taking into account only this, that both have two constant and similarly placed nodes, the logical course would be to unite them. But if the apparently unquestionable derivation of *H. radiata* from the Devonian species of *Hollina* is considered, the impropriety of the suggested reference cannot be ignored. *Ulrichia* is one of the Primitiidae; *Hollina* is a derivative—presumably somewhat atavistic—of Beyrichiidae.

As is evident from several preceding references in the paper to *Hollina*, the writers now regard the resemblance of certain species to *Ctenobolbina*, and of others to *Bollia*, as atavistic stages in the Devonian and Mississippian evolution of the typical Beyrichian stock, and not as survivals of the generic types to which they were originally referred. Ulrich placed most of the Devonian species under *Ctenobolbina* because of their general similarity in form, location, and range of variation to the *C. subcrassa* group of that genus, while the later *H. granifera* was referred to *Bollia* solely because the ventral union of its two nodes forms a loop precisely like the inner loop of typical species of that genus. In neither case were the characters now relied on, such as the two constant rounded nodes and the broad frill on the posterior and ventral margins, taken into account, and the genetic relations to *Beyrichia*, though suspected, were not appreciated as they should have been. "Loops" strikingly like that in *Bollia* occur in other types. This was recognized by Ulrich in 1894* in discussing *Drepanella bigeneris*, a notable instance of this kind.

Subfamily KLÆDENELLINÆ.

Genus KLÆDENELLA, new.

Beyrichia (part) JONES and AUTHORS.

Klædenia (part) JONES, ULRICH, and most AUTHORS.

Bollia? (part) ULRICH, Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 669.

Carapace small, strongly convex, elongate, somewhat barrel-shaped, the length usually less than 1.5 mm.; dorsal edge nearly straight, ventral edge usually somewhat concave, ends approximately equal in height but differing in outline, the antero-dorsal angle often rectangular and always more distinct than the post-dorsal. Valves unequal, the right overlapping the left around the ends and the ventral side. Of the lobation, the constant features are two sharply impressed vertical or slightly oblique furrows, separated by a narrow lobe, in the posterior half. In the more simple forms, these furrows extend only about half across the valve. Anterior half may be uniformly convex, but, as a rule, is more or less clearly bisected vertically by a straight or curved furrow. When present, this anterior furrow

* Geol. and Nat. Hist. Surv. Minnesota, Final Rept., III, Pt. 2, 1894, p. 671.

often produces an appearance suggesting the "loop" of a *Bollia*. Surface generally smooth and polished, and without ornamental markings.

Genotype.—*Klædenella pennsylvanica* (*Klædenia pennsylvanica* Jones).

Of unquestioned species of this genus, some eight or ten, two of them perhaps being merely varieties, are contained in the collections of the U. S. National Museum. These range in time from the Clinton to middle Devonian. A British Carboniferous species, published by Jones and Kirkby under the name *Beyrichia? bicaesa*, probably belongs to this genus. Except this and the two Devonian species, all the others are confined to the Silurian rocks of the Appalachian province. As a rule, the species are exceedingly prolific in the way of individuals, the layers of limestone in which they occur being almost literally made up of their remains. In most cases they occur as entire shells, which, being easily freed from the matrix, are admirably suited for detailed study.

Only about half of the known forms have been described, and one of these (described as *Beyrichia trisulcata* by Hall) has never been adequately figured. *Klædenia pennsylvanica*, as figured by Jones in 1889^a, includes two distinct species and a variety, which are represented by thousands of specimens in the material available to the writers. The form represented by Jones's figures 5a, b, c, d, and 6 is accepted as the *Klædenella pennsylvanica*. His figures 8 and 9 are regarded as based on examples of our *K. turgida*, new species,^b while 7a and 7b probably represent a variety of the latter, here distinguished by the subordinate name *ventrosa*.^c

^a Amer. Geol., IV, p. 341, figs. 5-9.

^b *Klædenella turgida* is distinguished from *K. pennsylvanica*, as here restricted, by the strong development of the anterior sulcus. This sulcus delimits a well-marked anterior lobe and produces a somewhat concentric arrangement of the lobes behind it, the effect being quite different from the usual appearance of *K. pennsylvanica*.

Length of a normal right valve, 1.10 mm.; height, 0.64 mm.; length of a short left valve, 0.97 mm.; height, 0.60 mm. See Plate XLIII, figs. 6, 7.

Formation and locality.—Coeymans limestone, Cumberland, Maryland.

Cotypes.—Cat. No. 53278, U.S.N.M.

^c This form is more like *K. pennsylvanica* than *K. turgida* in lobation of the valves, being without a well-marked anterior sulcus, but in the less elongate form and general aspect it is so like *K. turgida* that it has been placed as a variety of this species. Its main peculiarity lies in a ventral swelling which causes an apparent break in the antero-median lobe. The ventral flange is unusually well developed and the series of granules along the antero-ventral edge has not been observed in any other species of the genus. See Plate XLIII, fig. 8.

Formation and locality.—Coeymans limestone, Cumberland, Maryland.

Holotype.—Cat. No. 53279, U.S.N.M.

The genus is divisible into two sections, the first comprising the greater part of the known species, among them the genotype. In this group the posterior and median furrows are shorter than in the second, and the anterior furrow either wanting or more or less well developed. In the second group, of which *Beyrichia halli* Jones (*Bollia halli* Ulrich) is a good example, the posterior and anterior furrows are long, subequal, and extending nearly or quite across the valve. The general expression is rather strikingly dissimilar in the two groups, but on close comparison it is found that the differences are not essential and, moreover, that the extremes are bridged by connecting links.

The *Klædenella halli*, as it should now be called, simulates *Bollia symmetrica* (Hall) to such a degree as to suggest its derivation from that earlier Silurian (Rochester shale) species. The *Bollia*, however, has not overlapping valves as has the *Klædenella*. Besides, the latter type appears to have been established already in Clinton time, indicating that its ancestors are to be looked for among Ordovician



FIGS. 61-64.—61. LEFT VALVE OF *BOLLIA SYMMETRICA* (HALL). 62. RIGHT VALVE OF *KLÆDENELLA HALLI* (JONES). COPIED FROM JONES. 63. RIGHT VALVE OF *KLÆDENELLA TURRIDA*, NEW SPECIES. 64. RIGHT VALVE OF *BEYRICHIA? PARALLELA* ULRICH. $\times 20$. (AFTER ULRICH.) THESE FIGURES ILLUSTRATE (1) THE SIMILARITY OF EXPRESSION OF *BOLLIA* TO *KLÆDENELLA*, AND (2) THE POSSIBLE DERIVATION OF *KLÆDENELLA* FROM THE RICHMOND SPECIES *BEYRICHIA? PARALLELA*.

species. Such a possible ancestor is found in the peculiar Richmond species described by Ulrich as *Primitia* or *Beyrichia parallela*. The general form of the valves and the lobes are sufficiently like *Klædenella* to encourage the belief that it fulfills the requirements of the case. It is to be regretted, however, that only separated valves of this Richmond species are known, so that it is difficult, if not impossible, to decide the question by showing agreement also in the matter of inequality of its valves.

Because of the mentioned resemblance to *Bollia*, Ulrich in 1894 tentatively referred species of the *K. halli* section, including *K. clarkei* (*Beyrichia clarkei* Jones) and two new species, to *Bollia*. Although this reference is now thought to have been in error, it must be admitted that it is not easy to show just why the group was not descended from *Bollia regularis* and *B. symmetrica*. At that time the senior author had very few specimens of the type now discriminated under the name *Klædenella*, and *K. halli* and *K. clarkei* were known to him only from the rather indefinite figures and descriptions published by Jones, which neither showed nor mentioned the unequal-

ity of their valves. Hence, he had had no opportunity to observe the principal evidence in the case, namely, the transition from *K. pennsylvanica* to *K. clarkei*,^a and the fact that while the valves of *Bollia* are equal, those of *Klædenella* are unequal. In passing, it may be said that *Bollia* is regarded as an early derivative of *Primitia*, that it established an independent line having no subsequent connection with the true Beyrichiidæ and that it represents the most complex stage of lobation attained by the Primitiidæ.

The Klædenellinæ are Beyrichiidæ with valves more or less distinctly overlapping. As a rule, the overlap is confined to the ventral side and ends. *Beyrichiopsis* Jones and Kirkby, *Beyrichiella* Jones and Kirkby, *Jonesina*, and *Kirkbyina*, new genera, are referred to the subfamily. Technically *Kyammodos* Jones fulfills the requirements, but, being convinced of the genetic alliance of that genus to *Klædenia*, the writers hesitate to remove it from the Beyrichiidæ.

CARBONIFEROUS BEYRICHIIDÆ.

Two years ago,^b the writers had occasion to discuss the Carboniferous Beyrichiidæ. Among the conclusions were (1) that the group of *Beyrichia radiata* is worthy of generic separation, a view carried out in the present communication by the erection of the new genus *Hollina*; (2) that the remaining, inequivalved Beyrichiidæ, including *Beyrichiopsis*, *Beyrichiella*, and *Synaphe*, of Jones and Kirkby, besides a number of species referred by these authors to *Beyrichia*, probably constituted a single comprehensive genus; (3) that *Synaphe* should be relegated to synonymy under *Beyrichiella*; and (4) that two subgenera might be recognized, of which *Beyrichiopsis* would be one. Similar conclusions were reached in the present more comprehensive study of the family, the principal difference being that *Beyrichiopsis* and *Beyrichiella* are recognized as genera, and a new genus, *Jonesina*, is proposed instead of "a second subgenus." Finally, a fourth genus, *Kirkbyina*, is proposed for two species doubtfully referred to *Beyrichiella* by Jones and Kirkby, and which were not considered in 1906.

^aA new variety of *K. clarkei* is here instituted under the name of *paupera* of which the following are the characteristics: The valves and the ridges especially are thinner than in the species itself, giving the whole a somewhat emaciated appearance. Furthermore, the furrows present somewhat irregularly distributed but numerous papillæ which have not been observed in the typical form of the species. See Plate XLIII, fig. 5.

Formation and locality.—Coeymans limestone, Cumberland, Maryland.

Holotype.—Cat. No. 53280, U.S.N.M.

^bProc. U. S. Nat. Mus., XXX, 1906, pp. 151-155.

Considerable instability of character in these inequivalved Beyrichiidae was recognized in the preceding publication; also the fact that many of them exhibited more or less obvious resemblances to Ordovician and Silurian types. These facts were explained as resulting from reversion and arrested development incident to the degeneration and extinction of the family in Carboniferous time.

In now recognizing four genera instead of a single broad genus, it is not intended to convey the impression that the writers have materially changed their opinions respecting the close alliance of the several groups. Neither are the groups of species thought to be more natural genetic associations than they were believed to be in 1906. It is only in deference to the matter of convenience in classification, and to insure greater clearness and brevity in definition, that the change from one to four is made. Considering them as one genus, it seemed impossible to draw up a reasonably brief diagnosis that would not cover a variety of really very distinct pre-Carboniferous types. Though it can not be denied that the whole group is bound together by intimate alliances, it is yet a fact that but a single feature of generic or family rank pertains to all its members, namely, slight inequality of the valves. But this feature, of course, is not peculiar to this group, since it occurs in many otherwise very different Ostracoda. By dividing the group into four genera and using the feature common to them all as characterizing a subfamily of Beyrichiidae, the resulting classification is at least convenient and probably as natural as it can be made so long as established characters are consulted as not less important than genesis in the forming of zoological classifications.

In the present arrangement of the Carboniferous Klædeniellinae, all of the British species described by Jones and Kirkby are accounted for save *Beyrichia tuberculospinosa*, *B. multiloba*, and *B. varicosa*. The published figures of these three species^a indicate peculiarities, the value of which it would be unwise to decide without first verifying them by study of good specimens. Until that is done, it is advisable to leave them in the still large residuum of undetermined and doubtful species of *Beyrichia*. In the meantime it may be said that *B. multiloba* and *B. varicosa* would have been placed with *Jonesina* were it not that in both cases, as figured by Jones and Kirkby, the left instead of the right valve is the smaller. In this respect the two species agree with *Klædenella*. The figures of *B. tuberculospina* are indecisive on this point, and the most that may be said of this species at the present time is to suggest that it may be an aberrant *Hollina* and as probably related to *H. longispina*.

^a Jones and Kirkby, Ann. and Mag. Nat. Hist. (5), XVIII, 1886, pl. viii.

Beginning with the most simple type, the genera may be defined briefly as follows:

Genus KIRKBYINA, new.

Beyrichiella ? JONES and KIRKBY, Ann. and Mag. Nat. Hist. (5), XVIII, 1886, p. 260.

Carapace small, less than 1 mm. in length, rather short, subovate to subquadrate, ventricose, thickest anteriorly, with a simple primitian sulcus about the middle of the dorsal half. Valves unequal, the right slightly larger and overlapping the edges of the left.

Genotype.—*Kirkbyina reticosa* (*Beyrichiella* ? *reticosa* Jones and Kirkby).

In the same paper ^a Jones and Kirkby describe a second more tumid species, likewise referring it doubtfully to *Beyrichiella* under the name *B. ? ventricornis*. At present only these two British species may be safely placed in the genus *Kirkbyina*. There are a few as yet unstudied, Primitia-like Ostracoda in American deposits of Carboniferous age that may turn out to belong here.

Kirkbyina resembles *Primitia*, but is readily distinguished by its overlapping valves and thicker anterior end. In *Primitia* it is the posterior half that is usually the thicker. *Beyrichiella* has a more elongate shell and broader sulcus, while its left valve and not the right is the larger.

Genus BEYRICHIELLA Jones and Kirkby.

Beyrichiella JONES and KIRKBY, Geol. Mag., Dec. 3, III, 1886, p. 438: Proc. Geol. Assoc., IX, 1886, p. 506.

Beyrichiella (part) ULRICH and BASSLER, Proc. U. S. Nat. Mus., XXX, 1906, pp. 151-155.

Synaphe JONES and KIRKBY, Trans. Royal Dublin Soc. (2), VI, 1896, p. 190.—ULRICH and BASSLER, Proc. U. S. Nat. Mus., XXX, 1906, p. 152.

Kirkbyia COSSMANN, Revue Critique de Paleozoologie, III, 1899, p. 45 (proposed for *Synaphe*, preoccupied).

Carapace small, 1 mm. or less in length, elongate subquadrate, thickest anteriorly, with a rather broad median sulcus giving the shell a bilobed aspect; a low, transverse ridge in the ventral part cuts off the sulcus and unites the lower parts of the two lobes. Valves unequal, the edge of the smaller right valve being set into the overlapping ventral and end parts of the larger left valve.

Genotype.—*Beyrichiella cristata* Jones and Kirkby.

The writers fail to see more than specific differences between *B. cristata* and *Kirkbyia annectens*, the type of *Synaphe* Jones and Kirkby (not *Synaphe* Huebner). It is, therefore, placed here as a

^a Ann. and Mag. Nat. Hist. (5), XVIII, 1886, p. 260.

second species of *Beyrichiella*. A third, the only known species from American strata, was described by Ulrich as *Ulrichia confluens*. Viewed in the narrow sense in which this genus was proposed and in which it is now thought desirable to recognize it, *Beyrichiella* is clearly distinguished from other members of the subfamily. The shell is relatively longer than that of *Kirkbyina* and its larger valve is not the right as in that genus, but the left. The lobation of the valves is also less simple, the low ventral ridge, connecting the two larger lobes, being a character not observed in *Kirkbyina*. The general shape of the carapace is decidedly like that of *Beyrichiopsis*, but the characteristic rounded, median—or rather post-median—node of that genus is wanting in *Beyrichiella*.

Genus BEYRICHIOPSIS Jones and Kirkby.

Beyrichiopsis JONES and KIRKBY, Geol. Mag., Dec. 3, III, 1886, p. 434; Proc. Geol. Assoc., IX, 1886, p. 506; Quart. Journ. Geol. Soc. London, XLII, 1886, p. 506.

Beyrichiopsis ULRICH and BASSLER, Proc. U. S. Nat. Mus., XXX, 1906, p. 152.

Carapace small, about 1 mm. in length, oblong, subquadrate to sub-elliptical, straight on the dorsal side, tapering slightly and thickest anteriorly; on the whole, rather strongly convex. A broad based, rounded swelling or lobe occupies the greater part of the anterior half. A second, smaller rounded eminence occurs behind the middle and usually above the mid-height of the valve. It is often surrounded by a slight depression usually deepest on the anterior side. Free edges of valves usually with a broad, spiny frill; in other cases merely denticulate. Two or three thin, crest-like ribs commonly cross the surface in a longitudinal direction.

Genotype.—*Beyrichiopsis fimbriata* Jones and Kirkby. Other typical species are *B. cornuta*, *B. subdentata*, *B. fortis*, *B. granulata*, and *B. simplex*, all described by Jones and Kirkby from British Carboniferous specimens.* Two new species in the Ulrich collection in the U. S. National Museum were collected from the basal shales of the Tullahoma formation in central Tennessee. One of these has a frill like *B. fimbriata*, the other is more like *B. cornuta*.

Compared with the other genera of the subfamily Klœdenellinæ, *Beyrichiopsis* is distinguished at once by the small, rounded post-median node. Otherwise the genus is not greatly different from *Beyrichiella*, its nearest ally, the usual presence of a spiny marginal frill being of subordinate importance. Another difference, however, is found in the transverse ventral ridge seen in *Beyrichiella* but which is absent in *Beyrichiopsis*.

* Geol. Mag., Dec. 3, III, 1886, pp. 434-437.

B. simplex and *B. granulata*^a depart somewhat from the other species in the more subdued development of both the anterior and the median lobes. These two species strongly resemble *Klædenia*. Indeed, it is difficult to point out satisfactory differences. However, as that genus became almost extinct with the close of the Silurian, it seems highly unlikely that these Carboniferous species were directly connected with it.

Genus JONESINA, new.

Beyrichia (part) JONES and KIRKBY, Ann. and Mag. Nat. Hist. (5), XVIII, 1886, p. 258; Geol. Mag., Dec. 3, III, 1886, p. 438.

Beyrichtella (part) ULRICH and BASSLER, Proc. U. S. Nat. Mus., XXX, 1906, pp. 151-155.

Carapace small, about 1 mm. in length, usually elongate, the outline varying from subelliptical to oblong or approximating a parallelogram; greatest thickness in anterior half. Valves strongly convex, variously lobed, unequal, the left being the larger, sometimes overlapping the edge of the right on all sides. The most simple types (*J. craterigera* and *J. arcuata*) are marked with a rather deep dorsal sulcus situated somewhat behind the middle. The whole area in front of this sulcus may be almost uniformly convex, or a node may be obscurely defined in its post-dorsal quarter (that is, just in front of the sulcus). Behind the sulcus a more clearly defined node is always observable. In more complex species (*J. fastigiata*) three nodes are distinguishable, two, subequal, situated on opposite sides of the main sulcus, and a larger, less definitely outlined, lobe occupying the anterior third. Finally, in *J. fodicata*, the anterior lobe is divided by the separation of a node simulating the other two in size and form, while all three nodes will appear as connecting below with a low marginal ridge. A more or less obscure and variable ridge commonly unites the two median nodes, occasionally producing an effect simulating *Bollia*.

Genotype.—*Jonesina fastigiata* (*Beyrichia fastigiata* Jones and Kirkby).

The following additional species are referred to *Jonesina*: *J. arcuata* (Bean) (as figured by Jones and Kirkby under the genus *Beyrichia*),^b *J. bradyana* (*Beyrichia* Jones and Kirkby),^c *J. craterigera* (*Beyrichia* Brady Ms., Jones and Kirkby),^d *J. fodicata* (*Beyrichia*

^a Jones and Kirkby describe the latter as a variety of *B. fortis*. It seems to the writers as allied to *B. simplex* rather than *B. fortis*, the post-median node as well as the general expression of the valves, aside from the surficial crests being the same as in the former and quite different from the latter.

^b Geol. Mag., Dec. 3, III, 1886, p. 438, pl. XII, figs. 12-14.

^c Idem., fig. 11.

^d Idem., figs. 7a, 7b.

Jones and Kirkby),^a all from the Carboniferous rocks of Great Britain, and *J. bolliiformis* and var. *tumida* (*Beyrichiella* Ulrich and Bassler),^b and *J. gregaria* (*Beyrichiella* Ulrich and Bassler)^c from rocks of Pennsylvanian age in Kansas and Texas. Other American species are known, but remain to be described.

Jonesina sometimes resembles *Klædenella* to a marked degree. This is true especially of *J. craterigera*, but with entire specimens the observer should experience little difficulty in distinguishing them, the matter of relative size of the valves being reversed in the two genera. In the older genus the right valve is the larger, whereas in *Jonesina* it is the left.

In correlating the nodes of *Jonesina* with those of a typical *Beyrichia*, it is to be observed that the median lobe of the latter corresponds to the post-median node of *Jonesina*, the one, two, or three nodes in front of the median sulcus being equivalent to the single or dissected anterior lobe of *Beyrichia*. Obviously the location of the homologous parts in the two genera is widely different.

^a Ann. and Mag. Nat. Hist. (5), XVII, 1886, p. 258, pl. VIII, figs. 4-6.

^b Proc. U. S. Nat. Mus., XXX, 1906, p. 158, pl. XI, figs. 7-11.

^c Idem., fig. 18.

EXPLANATION OF PLATE XXXVII.

Figs. 1-4. Group of *Beyrichia tuberculata*.

1. Four views of a left valve of *Beyrichia tuberculata*.
2. Similar views of a right valve of female individual of same.
3. Four views of a right valve of *B. tuberculata bigibbosa* Reuter.
4. Similar views of a right valve of *B. noettingi* Reuter. All the figures are magnified five times and copied from Reuter.

5-10. Group of *Beyrichia klædenti*.

5. Two views of a left valve of *Beyrichia maccoyana sulcata* Reuter, $\times 8$.
6. Similar views of left valve of female individual of same, $\times 8$.
7. Left valve of *Beyrichia lindstromi* Kiesow, $\times 8$.
Figs. 5 and 6 are copied from Reuter and fig. 7 from Kiesow.
8. Left and right valves of *Beyrichia moodeyi*, new species, $\times 10$.
Cayuga formation, Cacapon, Maryland.
- 9, 10. Right and left valves of *Beyrichia waldronensis*, new species, $\times 10$.
Niagara (Waldron), Waldron, Indiana.

11-13. Group of *Beyrichia buchiana*.

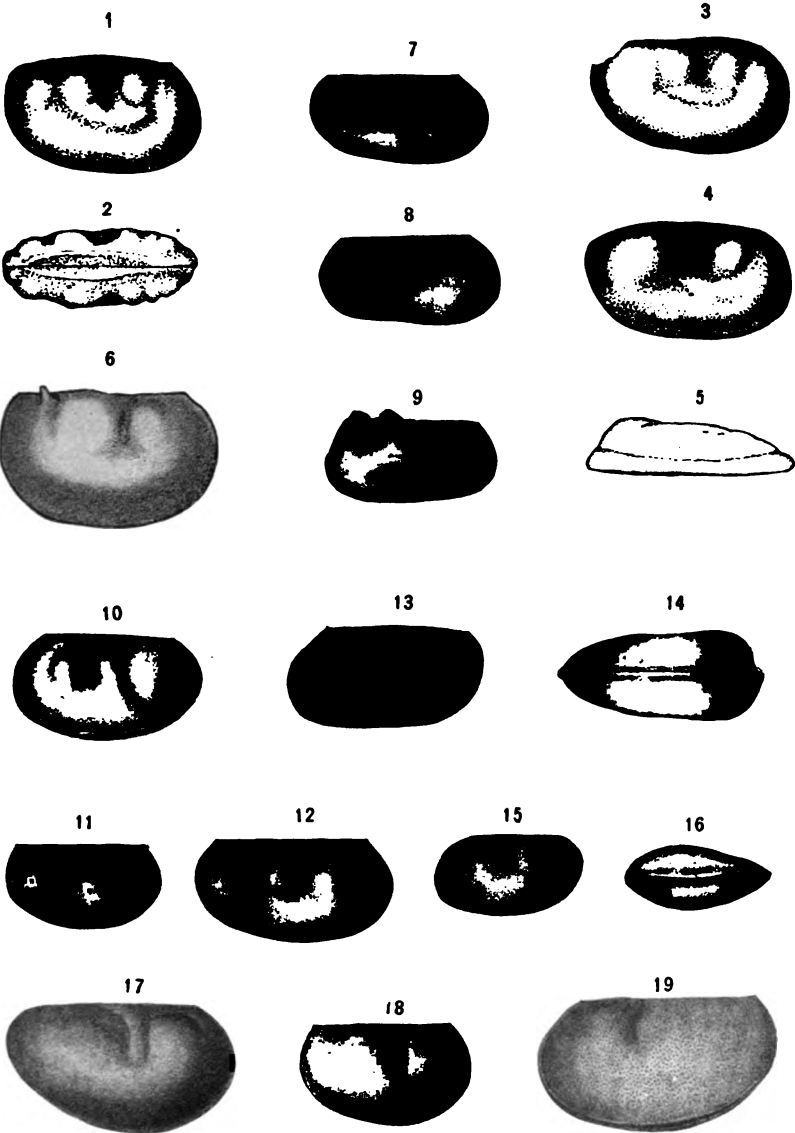
11. Left valve of *Beyrichia buchiana* Jones, $\times 8$. Copied from Jones.
12. Four views of a right valve of *Beyrichia buchiana angustata* Reuter, $\times 6$. (After Reuter.)
13. A right valve of *Beyrichia lauensis* Kiesow. (After Kiesow.)

14, 15. Group of *Beyrichia salteriana*.

14. Lateral and ventral views of a right valve of *Beyrichia salteriana* Jones, $\times 10$. (After Reuter.)
15. Right valve of *Beyrichia granulosa* Hall. (After Hall.)

16, 17. Group of *Beyrichia clavata*.

16. Right valve of *Beyrichia clavata* Kolmodin. (After Kiesow.)
17. Right valve of *Beyrichia jonesii* Boll. (After Kiesow.)



JONESINA.

FOR EXPLANATION OF PLATE SEE PAGE 340.



B. KEMP WELCH,

SMITHSONIAN INSTITUTION
UNITED STATES NATIONAL MUSEUM
Bulletin 65

2

DENDROID GRAPTOLITES OF THE
NIAGARAN DOLOMITES AT
HAMILTON, ONTARIO

THETA TAU FRATERNITY
Epsilon Chapter
Gift of *C. M. Mitchell*

Compiled by

RAY S. BASSLER
*Curator, Division of Invertebrate Paleontology
U. S. National Museum*



WASHINGTON
GOVERNMENT PRINTING OFFICE
1909

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II

ADVERTISEMENT.

The scientific publications of the National Museum consist of two series—the *Bulletin* and the *Proceedings*.

The *Bulletin*, publication of which was begun in 1875, is a series of more or less extensive works intended to illustrate the collections of the U. S. National Museum and, with the exception noted below, is issued separately. These bulletins are monographic in scope and are devoted principally to the discussion of large zoological and botanical groups, faunas and floras, bibliographies of eminent naturalists, reports of expeditions, etc. They are usually of octavo size, although a quarto form, known as the Special Bulletin, has been adopted in a few instances in which a larger page was deemed indispensable.

This work forms No. 65 of the Bulletin series.

Since 1902 the volumes of the series known as "Contributions from the National Herbarium," and containing papers relating to the botanical collections of the Museum, have been published as bulletins.

The *Proceedings*, the first volume of which was issued in 1878, are intended as a medium of publication of brief original papers based on the collections of the National Museum, and setting forth newly acquired facts in biology, anthropology, and geology derived therefrom, or containing descriptions of new forms and revisions of limited groups. A volume is issued annually, or oftener, for distribution to libraries and scientific establishments, and in view of the importance of the more prompt dissemination of new facts a limited edition of each paper is printed in pamphlet form in advance.

RICHARD RATHBUN,

*Assistant Secretary, Smithsonian Institution,
In Charge of the United States National Museum.*

WASHINGTON, U. S. A., June 20, 1909.

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DENDROID GRAPTOLITES OF THE NIAGARAN DOLOMITES AT HAMILTON, ONTARIO.

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INTRODUCTION.

The large collection of graptolites which has been accumulating in the U. S. National Museum for many years, mainly through transfer from the U. S. Geological Survey, has recently been classified and so arranged that all of the specimens are now available for study. Fifteen years ago, Dr. R. R. Gurley, then connected with the U. S. Geological Survey, undertook a monographic study of the graptolites of the world with specimens now constituting the greater portion of the Museum's present collection as the basis for his work. Doctor Gurley accumulated a mass of manuscript relating chiefly to the bibliography of these organisms, but his resignation from the survey brought the work to an end. Nothing further was done with either the specimens or manuscript until 1905, when an arrangement was made with the director of the New York State Museum, whereby Dr. Rudolph Ruedemann, assistant state paleontologist, should study Doctor Gurley's unpublished types and use as much as possible of the manuscript in connection with his studies on the graptolite faunas of New York. In his preface to Part 2 of the Graptolites of New York,^a Doctor Ruedemann writes the following:

Our request [for the loan of Gurley's types] was most liberally granted by the authorities of the U. S. Geological Survey and of the National Museum, but with the specimens there was delivered to us the voluminous unfinished manuscript of Gurley's monograph of the graptolites with the understanding that we should use as much as possible of the same, and thus assure to Doctor Gurley's long labors the credit to which they are entitled. The author has gladly availed himself of Gurley's work, which even in its fragmentary form bears witness not only of the admirable patience and enthusiasm of its author, but also of his keen power of observation.

In justice to both Doctor Gurley and myself a full statement of what this voluminous manuscript contains and what has been used for this memoir should be given in this place.

^a New York State Museum, Memoir 11, 1908.

The greater part of the manuscript consists of copies of the descriptions, and translations of those in other than the English language, of all foreign species of graptolites together with a full bibliography of all species described up to 1896. It is obvious that it was the author's intention to produce a monograph of all the graptolites of the world.

Another part of the manuscript contains the history and synonymy of the American species. In this work Doctor Gurley had evidently made special efforts to trace the history of many of the cryptic names of the earlier geologists, as those of the graptolites mentioned in the reports of the first geological survey of New York by Emmons and others. These notes are fairly complete; they have been used here as far as the scope of our work allowed, and due credit given the author.

In the description of the North American graptolites Gurley had not proceeded beyond the Dendroidea and a part of the Graptoloidea of the Lower Champlainic. The former consist in the large majority of the Niagara forms from Hamilton, Canada, which lie without our field, and the descriptions of the latter faunas are entirely based upon Canadian material.

In another paragraph Doctor Ruedemann has the following to say regarding Doctor Gurley's monograph:

On the whole, it may be fairly said that Doctor Gurley has printed in his preliminary publication in the Journal of Geology all that was new or especially worthy of publication, namely, the descriptions of all new species—with the exception of a few Dendroidea—and his observations on the morphology of certain hitherto incompletely known species (e. g., *Clathrograptus geinitzianus*). Still there was enough left in the manuscript to make it a welcome help to the writer in many ways. Its extensive bibliography of the graptolites, which is practically complete to 1896, might be published as a separate bulletin, as also eventually the Dendroidea. This done, full justice, I believe, would have been rendered to Doctor Gurley's assiduous labors on the graptolites.

From time to time attempts have been made to arrange the Gurley manuscript so that portions of it at least could be prepared for publication, but it finally became apparent that the dendroid forms from Hamilton, Ontario, were all that could be said to be available for this purpose, without a complete restudy and redescription of the forms. At the request of the secretary of the Smithsonian Institution I have arranged the present article, using Doctor Gurley's descriptions and drawings as a basis, but in order to illustrate the fauna properly additional photographs were necessary. As these are my own work, it would be unfair to attribute any mistakes in them to Doctor Gurley, and they have, therefore, been designated accordingly on the descriptions of the plates. For the same reason, it may be noted that the identification and arrangement of the drawings, the descriptions of the text figures and plates, and other matters, exclusive of the descriptions of species and notes accredited to Doctor Gurley, have been introduced by me.

While the present work has been in part that of compilation, yet it is only fair to say that in order to do the subject justice, a restudy

of the various collections of Hamilton, Ontario, graptolites was necessary. This restudy resulted in the suppression of a number of Gurley's manuscript names and descriptions, which in themselves gave evidence that they did not represent the author's final judgment.

But few of the specimens in the national collection were labeled so that they could be assigned to their proper species without further study. Fortunately, in many instances the illustrated specimens were numbered and mentioned by number in the manuscript. Specimens in the collections of the New York State Museum and the Walker Museum of Chicago University, kindly loaned by the authorities of these respective institutions, proved to be better supplied with labels, and the study of them helped greatly in the identification of the species.

A few words in connection with the preparation of the accompanying illustrations may be of some interest. Doctor Gurley's drawings were prepared by first inking in the graptolite as seen on ordinary blueprint photographs of the specimens, and then bleaching out the background. This method, although satisfactory in many cases, did not give good results with poorly defined specimens, so in the additional illustrations which were made the following method of procedure was used: The objects were first treated to a thin coat of French retouching varnish, which brought out the details of even the poorest material fairly well. Specimens so coated are in excellent shape for study, but on account of the reflection of light from the slightly polished surfaces, do not lend themselves well to photography. This difficulty was overcome by photographing the specimens immersed in water.

The wonderful fauna of dendroid graptolites at Hamilton, Ontario, has been collected with untiring enthusiasm by Col. C. C. Grant, to whom science is indebted for the discovery of many new species. Colonel Grant has published interesting popular accounts of the geologic features at Hamilton in the *Journal and Proceedings of the Hamilton Association*, and has likewise figured, without description, some of the more interesting graptolites. Up to the present time the description of these forms has been mainly from the pen of Prof. J. W. Spencer, whose articles upon the subject are noted in the bibliography of the species beyond. More recently Doctor Ruedemann has described the Niagaran forms occurring in New York.

In the present article I have endeavored to carry out Doctor Gurley's plan of publishing complete descriptions of these dendroid graptolites. For this reason the original descriptions of Spencer and others are inserted whenever they have been thought to add to the completeness of the work. Likewise all of the species have been illustrated, either by copies of the original figures or by additional drawings and photographs, and in some cases by both.

The destruction by fire of the museum building at the University of Missouri some years ago resulted in the loss of all of Spencer's original types. No additional specimens of some of his species have come to hand in later collections, so that such species must rest on their descriptions and figures alone. However, it must be stated that all specimens quoted in the descriptions, other than Spencer's figured types, are still extant.

Professor Spencer has published a detailed section of the rocks at Hamilton, which is repeated here for ready reference of the graptolites to their horizon.

Geologic section at Hamilton, Ontario.^a

This section was measured along the brow of the escarpment at the city of Hamilton, between the ravine at the head of James street and the "Jolly Cut" road, about half a mile to the eastward.

NIAGARA FORMATION.

	Thickness in feet.
Bed No. 12. Thin gray dolomites with an abundance of cherty nodules. This bed is known as the "Chert bed," and forms the brow of the escarpment at Hamilton and eastward, being 388 feet above lake at head of James street. At head of Queen street this series is 19 feet thick-----	12.0
Bed Nos. 11 and 10. Argillaceous dolomites, with shaly partings—upper portion known as the "Blue Building beds." Beds 0.5–1 foot thick-----	15.5
Bed No. 9. Dark hard dolomitic shales and dolomites weathering to gray—and lower beds most shaly-----	10.5
Bed No. 8. Thick bed gray crystalline dolomite (nearly pure)-----	4.5
Bed No. 7. Argillo-arenaceous dolomite in beds from 1–1.5 feet thick-----	8.8
	<hr/> 51.3

CLINTON FORMATION.

Bed No. 6b. Earthly dolomite, with shaly partings-----	8.0
Bed No. 6a. Clinton shales, all dolomitic, with thin beds of harder rock, some of which are arenaceous, and others to a thickness of about 7 feet are arenaceous-ferruginous. The upper 9 feet may be considered as passage beds-----	76.9
Bed No. 5. Passage beds of argillaceous dolomites. (Top projecting portion is glaciated, and is 254 feet above lake)-----	8.8
	<hr/> 93.7

MEDINA FORMATION.

Bed Nos. 4 and 3. Coarse, gray sandstone—"Gray Band." This bed varies in thickness-----	6.5
Bed Nos. 2 and 1. Medina variegated red and green shales. Thickness from calculation of Dundas artesian well-----	538.5
	<hr/> 545.0
Total thickness-----	690.0

^a J. W. Spencer, Canadian Naturalist, X, 1883, p. 136.

All of the species and varieties noted in the following pages occur in the Niagaran limestone at Hamilton, the especial portion in the section being indicated under the descriptions. These limestones seem to belong entirely to the Lockport division of the Niagaran, although it is possible that beds 7 to 9 of the section represent the Rochester shale of western New York. This latter view is suggested by the fact that of the six species common to the Rochester shales and Lockport limestone, namely, *Dictyonema retiforme*, *D. polymorphum*, *D. subretiforme*, *Cyclograptus rotadentatus*, *Inocaulis plumulosus*, and *Acanthograptus walkeri*, two or three are limited to the shaly strata at the base of the Niagaran limestone, while the exact position of at least two more is uncertain. The essential unity believed by Ruedemann to exist between the graptolite faunas of the Rochester shale and the Niagaran limestone at Hamilton is therefore more doubtful.

DESCRIPTIONS OF GENERA AND SPECIES.^a

Order DENDROIDEA Nicholson.

Family DENDROGRAPTIDÆ Roemer.

Genus DENDROGRAPTUS Hall.

Dendrograptus HALL, Rep. Progr. Geol. Surv. Canada for 1857, 1858, p. 143; Geol. Surv. Wisconsin, I, 1862, p. 21; Geol. Surv. Canada, Decade 2, 1865, pp. 126, 127; 20th Rept. New York State Cab. Nat. Hist., 1868, p. 218, (rev. ed., 1868 [1870], p. 252).—CARRUTHERS, Geol. Mag., V, 1868, pp. 73, 130.—ZITTEL, Handbuch d. Pal., I, 1879, p. 289.—SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 562, 566; Bull. Mus. Univ. State Missouri, I, 1884, p. 16.—MILLER, North Amer. Geol. and Pal., 1889, p. 184.—JAMES, Journ. Cincinnati Soc. Nat. Hist., XIV, Pt. 2, 1892, p. 151.—FOSTA, Syst. Sil. Centre Boheme, VIII, Pt. 1, 1894, p. 165.—ROEMER and FRECH, Leth. geog., I Thell, Leth. Pal., I, 3 Lief., 1897, p. 577.—ELLES and WOOD, Mon. Brit. Graptolites, Pal. Soc., 1903, p. xii.—RUEDEMANN, New York State Mus., Mem. 7, 1904, p. 578.

Dendrograpsus NICHOLSON, Quart. Journ. Geol. Soc. London, XXIV, 1868, p. 142; Mon. Brit. Graptolitidæ, 1872, p. 127.

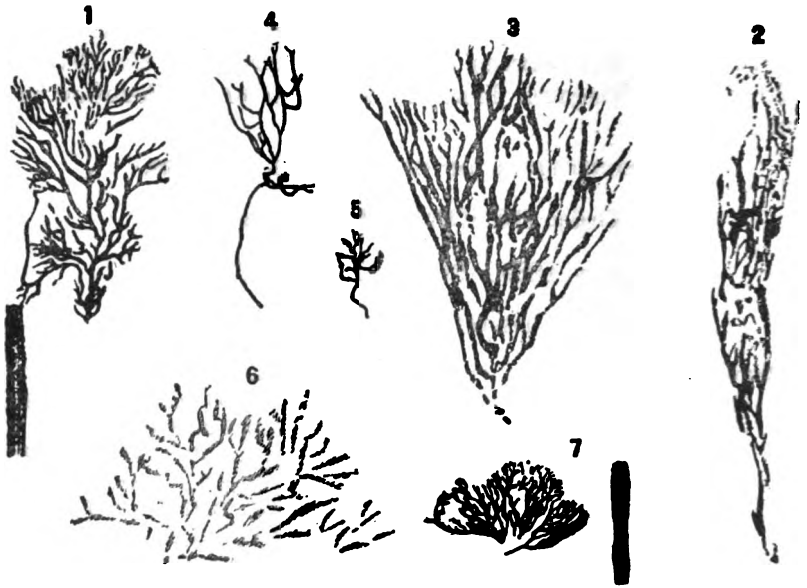
According to Ruedemann:

The genus *Dendrograptus* was created for forms with a strong main stem and a broad, spreading, shrub-like, variously ramifying frond. The thecæ are described as quite distinct and angular in some (the type-species of the genus, *D. hallianus* Prout), of obscure forms in others, while in still others they are shown only as round or elliptical pits or postules.

Genotype.—*Graptolithus hallianus* Prout. Upper Cambrian, Osceola Mills, Wisconsin. The species is also known from several localities in the Upper Cambrian of Tennessee and Alabama.

^a Unless otherwise stated, all of the text figures were made either by Doctor Gurley or under his supervision, and are of natural size.

Nine species of *Dendrograptus* are here noted, two of which are new. This is not the complete representation of the genus at Hamilton, Ontario, since Doctor Gurley's manuscript includes short descriptions, unaccompanied by illustrations, of three additional species, each of which is represented by a single specimen said to be in the New York state collections. As these specimens are inaccessible at the present time the descriptions are omitted. To complete the notes on this fauna, however, it may be added that one of these species is a very slender, rigid little form, with sharp, V-shaped bifurcations; the second has very thick stems and branches, the latter upright, close



FIGS. 1-7.—1, *DENDROGRAPTUS DAWSONI* SPENCER. A FROND NATURAL SIZE AND A BRANCH ENLARGED; 2, *D. DUBIUS* MILLER; 3, *D. RAMOSUS* SPENCER. A FROND WITH A BRANCH ENLARGED; 4, *D. PRAEGRACILIS* SPENCER; 5, *D. SPINOSUS* SPENCER; 6, *D. ? PROBLEMATICUS* SPENCER; 7, *D. FRONDOSUS* SPENCER. A FROND NATURAL SIZE AND BRANCH ENLARGED. (COPIED FROM SPENCER.)

together, and parallel, while the branches of the third are narrow at their origin, but widen uniformly to their bifurcations or free ends.

DENDROGRAPTUS DAWSONI Spencer.

Text figure 1.

Dendrograptus dawsoni SPENCER, Can. Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 568, pl. 1, fig. 5; Bull. Mus. Univ. State Missouri, No. 1, 1884, pp. 14, 18, pl. 1, fig. 5.—MILLER, North Amer. Geol. and Pal., 1889, p. 184.—GURLEY, Journ. Geol., IV, 1896, pp. 94, 308.

Doctor Spencer's description is as follows:

Frond erect and treelike. Stipe short, but extending upward and dividing into two or three principal branches, each bifurcating twice or thrice, and at the

same time giving off several slightly diverging branchlets at irregular distances on both sides. The lower part of the stipe or trunk also gives off several branchlets. The outline of the frond is cleft or divided into somewhat rounded lobes, with branches more or less upright. The corneous surface is strongly marked with striations. The cellular openings are oval on one side of the axis, as represented in figure 5a. However, there are undulations or swellings on some of the surfaces.

This little fossil is one of the most beautiful of the Graptolite family found in the Niagara formation. It is 4 cm. high and with a breadth of 2 cm., while the branches are less than half a millimeter thick and nearly double that distance apart. There is a strong resemblance to *D. fruticosus* of the Quebec group. Only one good specimen is in my possession.

Formation and locality.—This specimen was obtained by Colonel Grant in the dolomitic shales, below the chert bed of the Niagara formation, at the "Jolly-cut road," Hamilton, Ontario.

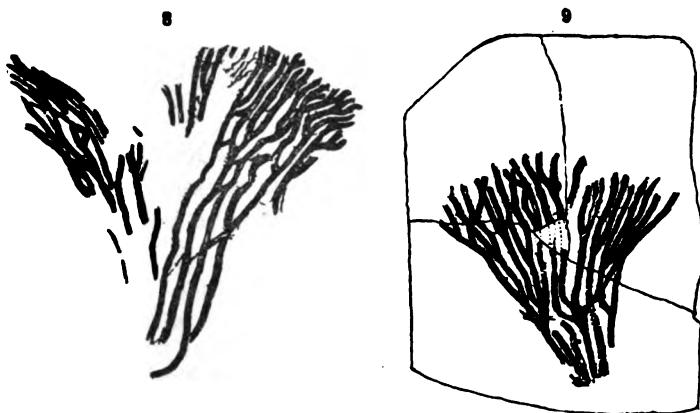
No additional specimens of this species occur in the later collections.

DENDROGRAPTUS DUBIUS Miller.

Text figures 2, 8.

Dendrograptus simplex SPENCER, Can. Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 567, 568, pl. 1, fig. 4; Bull. Mus. Univ. State Missouri, No. 1, 1884, pp. 14, 17, 18, pl. 1, fig. 4 (name preoccupied).

Dendrograptus dubius MILLER, North Amer. Geol. and Pal., 1889, p. 184.—GURLEY, Journ. Geol., IV, 1898, pp. 94, 308.



FIGS. 8-9.—8, *DENDROGRAPTUS DUBIUS* MILLER. AN INCOMPLETE FROND; 9, *DENDROGRAPTUS RAMOSUS* SPENCER. A FROND BRANCHING UNIFORMLY. (SEE ALSO PL. 1, FIG. 3.)

Doctor Spencer originally described this species under the name of *Dendrograptus simplex*, a name preoccupied and replaced by Miller with *D. dubius*. The original description of *D. simplex* is as follows:

Frond erect, with strong branches originating from a lengthy flexuous stipe, and diverging slightly above. The branches bifurcate only once or twice and are closely crowded together. Transverse bars are apparent in one or two places. The texture is corneous, with surface striated. On one side there are oval depressions marking the cell orifices; these are nearly a millimeter in length, and are situated about double that distance apart. Rudimentary branches are given off on each side of the stipe.

Of this species I have only one specimen. It is 5 cm. high, besides the single basal stipe, which is nearly 2 cm. long. The branches diverge from their initial points on the stipe until the summit is rather more than a centimeter broad, although there are six or seven branchlets present, each having the breadth of a millimeter and situated about the same distance apart.

Formation and locality.—This specimen was found in the Niagara dolomite at the "Jolly-cut road," Hamilton, Ontario.

A single specimen from the Niagara dolomite, Hamilton, Ontario, loaned by the Hamilton Museum (text fig. 8), agrees in all essential points with Spencer's description, and apparently represents this species. A drawing of this specimen was prepared by Doctor Gurley, whose manuscript also contains the following notes upon the species:

Evidently Spencer's figure represents a crushed or weathered specimen, so that such deviations from it as occur here are merely such as would be expected in better material. The branches mostly measure 0.8–1 mm. and are separated by about their own width or a little more. The branches are more numerous near the top, resulting in being more bushy in this region. This species is distinguished from the other species at this horizon by the stoutness of its branches and the size of the polypary.

DENDROGRAPTUS FRONDOSUS Spencer.

Text figure 7.

Dendrograptus frondosus SPENCER, Can. Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 568, 569, pl. 1, fig. 6; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 18, 19, pl. 1, fig. 6.—MILLER, North Amer. Geol. and Pal., 1889, p. 184.—GURLEY, Journ. Geol. IV, 1896, pp. 94, 308.

Several fragmentary specimens from the Niagara dolomites, in the collection of the U. S. National Museum, seem to belong to this species. They show no features in addition to those pointed out in the original description, which is as follows:

The frond is low and broadly flabellate, originating from a short slender stipe, which divides twice or thrice, after which the divisions extend to the summit of the several lobes, and send off branches at irregular distances on both sides. The branches give rise to lateral branchlets rather than bifurcations. The branches are short and slender, not exceeding one-third of a millimeter in thickness. The surface is striated; the cellular openings are minute and oval, but usually indistinct. Figure 6a represents an enlarged branch.

This graceful little frond is less than 2 cm. broad, and $1\frac{1}{2}$ cm. high.

Formation and locality.—It occurs in the Niagara dolomite at Hamilton, Ontario.

DENDROGRAPTUS RAMOSUS Spencer.

Text figures 3, 9. Plate 1, figure 3.

Dendrograptus ramosus SPENCER, Can. Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 567, pl. 1, fig. 3; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 17, pl. 1, fig. 3.—MILLER, North Amer. Geol. and Pal., 1889, p. 185.—GURLEY, Journ. Geol., IV, 1896, pp. 95, 308.

Doctor Spencer's description is as follows:

Frond moderately flabelliform. The base of the frond arises from a single stipe, and from near its summit most of the branches originate and moderately diverge above, with few bifurcations. The texture is corneous, with the surface strongly striated. The cellules are arranged along one of the margins of the branches, and have angular openings, processes, or cell denticles, marking these openings as in figure 3a, which is a branch enlarged.

The largest frond is 4 cm. high, exclusive of the basal stipe, of which the length of a centimeter is preserved. It expands above in straight radiating branches until the summit is rather more than 3 cm. across. The not-very-numerous branches are comparatively stout, being about a millimeter broad. The branches occasionally touch or overlap, but this arises from the manner in which they were compressed in the rock. This species is easily distinguished from any other of the group that is obtained at Hamilton.

Formation and locality.—This fossil is found in the more shaly dolomites below the "Chert beds" of the Niagara formation, at the "Jolly-cut road," Hamilton, Ontario.

This species is represented by two specimens in the Spencer collection, one of which has been photographed and figured by Doctor Gurley. (Text fig. 9 and Pl. 1, fig. 3.) According to this figure, the width of the branches is usually 0.8 mm., not infrequently reaching 1 mm.; a few as narrow as 0.6 mm. The branches are set about 17 to 20 in 25 mm. of width.

DENDROGRAPTUS PRAEGRACILIS Spencer.

Text figures 4, 10. Plate 2, figure 3.

Dendrograptus praegracilis SPENCER, Can. Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 569, pl. 1, fig. 7; Bull. Mus. Univ. State Missouri, 1, 1884, pp. 14, 19, pl. 1, fig. 7.—MILLER, North Amer. Geol. and Pal., 1889, p. 185.—GURLEY, Journ. Geol., IV, 1896, pp. 95, 308.

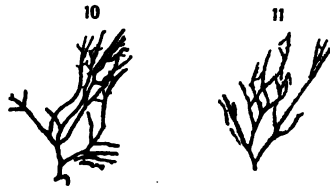
The original description is as follows:

Frond diffuse. The branches, few in number (three or four), originating from a long slender stipe, with each sending off smaller, very slender branchlets. Surface striated, and celluliferous on one side. Branches about a quarter of a millimeter broad and diverging considerably. The umbelliferous summit is about as broad as high (measuring 1½ cm., besides the long stipe).

The mode of branching and general appearance of this fossil closely resembles *D. gracilis* of the Quebec group, only it is much smaller.

Formation and locality.—It occurs in the Niagara dolomite at Hamilton, Ontario.

A single specimen (text fig. 10, and Pl. 2, fig. 3), from the Niagara cherty dolomite at Hamilton, Ontario, occurs in the U. S. National



FIGS. 10-11.—10, *DENDROGRAPTUS PRAEGRACILIS* SPENCER (SEE ALSO PL. 2, FIG. 3); 11, *DENDROGRAPTUS PHAINOTHECA*, NEW SPECIES. VIEW OF THE TYPE-SPECIMEN. (SEE ALSO PL. 2, FIG. 2.)

Museum collection, but it presents no features not already given in the above description.

Plesiotype.—Cat. No. 55293, U.S.N.M.

DENDROGRAPTUS SPINOSUS Spencer.

Text figure 5.

Dendrograptus spinosus SPENCER, Can. Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 569, pl. 1, fig. 8; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 19, pl. 1, fig. 8.—MILLER, North Amer. Geol. and Pal., 1889, p. 185.—GURLEY, Journ. Geol., IV, 1896, pp. 95, 308.

The original description is as follows:

Frond small and shrublike, with long flexuous stipe extending to the summit, and giving off branches, usually, alternate and at unequal distances, and diverging from each other at considerable angles. From both stipe and branches there are numerous spinellike branchlets, which sometimes have dichotomous terminations. The surface is striated, but the cellular structure is not preserved. The branches vary from one-third to one-half of a millimeter (in different specimens) in thickness, with somewhat greater distance between. The frond is usually twice as long as wide, and varies from 1½ to 2 cm. high.

Formation and locality.—This graceful little fossil is found in the cherty beds of the Niagara dolomite, at the "Jolly-cut road," at Hamilton, Ontario.

Doctor Gurley based the following description upon a specimen in the Spencer collection:

Portion of polypary seen about 15 by 10 mm., consisting of branches which measure 0.25–0.3 mm. None were seen as large as 0.5 mm. (as reported by Spencer). In their course they zigzag slightly, the spines proceeding from the convex angle of each bend. The stems seem to be somewhat wider at each angle, to contract above, and then again gradually widen up to the next angle, thus seeming as though formed of a series of similarly oriental cones; but the material is not perfectly satisfactory on this point. Division taking place irregularly, either by oblique lateral branching, or by dichotomy, not regularly unilateral, regularly bilateral, or regularly alternate. Thecae invisible.

DENDROGRAPTUS ? PROBLEMATICUS (Spencer).

Text figure 6. Plate 1, figures 1, 2.

Inocaulis ? problematica SPENCER, Can. Nat., VIII, 1878, pp. 458, 461; X, 1882, p. 165; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 586, pl. 5, fig. 3; Bull. Univ. Missouri, I, 1884, pp. 14, 36, pl. 5, fig. 3.—MILLER, North Amer. Geol. and Pal., 1889, p. 194.—GURLEY, Journ. Geol., IV, 1896, pp. 99, 309.

Doctor Spencer's original description is as follows:

Plantlike, with numerous slender bifurcating branches, radiating more or less from a common center, and resembling the branches of rootlets; texture corneous with irregular corrugations.

This species is of common occurrence, and is not easily mistaken for any other. The texture is not well preserved, appearing often as mere stains of dark

color on the surface of the stone. Its relations are somewhat doubtful, but it is easily distinguished from all the other species of the family by its rootlike character and slender branches (one-fortieth of an inch) often overlapping each other in an irregular manner. It occurs abundantly in the Niagara limestones of Hamilton, Ontario.

In his description published in 1884, the following additional notes are given:

Fronds aggregated, resembling branching rootlets * * *. The height of the individual frond does not appear to have been more than 2 or 3 cm., with comparatively few branches which are about three-fourths of a millimeter broad. Yet the individuals appear to have grown in bunches or groups, and one specimen indicates a large number of fronds originating from a common rootstock, whose branches, though only three centimeters high, cover 7 or 8 cm. in breadth.

* * * More commonly the fossil consists of an irregular mass of small branches lying together and occupying space on the stone not greater than 9 or 10 square cm.

Dr. Gurley's description and notes are as follows:

The specimens I have seen may be characterized as follows: Appearance of polypary as a whole, straggling and lax in the extreme, usually without any evident plan, consisting of numerous very flexuous, undulate or more or less undulate zigzag branches, which measure about 0.7-0.8 mm. in width, bifurcating at intervals, the resulting branchlets becoming subparallel and usually about 3 or 4 mm. apart. Thecae nowhere definitely outlined. Obscure indications of what may have been thecae are not wanting.

Perhaps the most characteristic single feature of this species is the irregular, straggling, diffuse arrangement of the branches. In part this is owing to their frequently over or under crossing one another. In one specimen (Pl. 1, fig. 1) the branches seem to be connected with, or arise from, a discoidal body, and I believe such origin to take place, though the specimen is not well enough preserved to place the matter beyond the possibility of doubt.

Horizon and locality.—Niagara dolomite and chert, Hamilton, Ontario.

Spencer notes the species as very common in the dolomite. This formation was not being quarried when the present collection was obtained. Hence my specimens, nine in number, are all from the chert. It is worthy of note that on five of these, *D. problematicus* is growing on *Rhinopora verrucosa*, and that it in one case acquires a pseudo-structure, a serration of the margin from puncture by the *Rhinopora* cells.

Whether this is a graptolite or not is somewhat uncertain. In some places marginal indentations are visible which greatly resemble those corresponding to thecae in other graptolites, but in no case are these unequivocal. Undoubtedly the species is not an *Inocaulis*. Among graptolites the mode of branching most nearly corresponds to that in *Dendrograptus*, and a provisional reference is made to that genus.

Plesiotypes.—Cat. No. 55294, U.S.N.M.; collection of Walker Museum, University of Chicago, No. 13510.

DENDROGRAPTUS PHAINOTHECA Gurley, new species.

Text figure 11. Plate 2, figure 2.

The following description of this species is by Doctor Gurley:

Polypary incomplete proximally, consisting only of several branches and branchlets. The two branches include an angle of about 70°. They are 0.5

mm. wide to the tips of the thecæ. It is probable that the latter are always situated on the side symmetrical with reference to the bisector of the angle included between the branches, occurring on the side toward it. They are straight cylindrical, inclined about 25° to the branch, with the apertural margin straight and perpendicular to the branch; they are set about 45 in 25 mm.

Horizon and locality.—This species is represented by a single specimen from the Niagara glaciated chert, at Hamilton, Ontario.

Holotype.—Cat. No. 55295, U.S.N.M.

DENDROGRAPTUS ONTARIOENSIS Bassler, new species.

Plate 1, figure 4.

Although this form was distinguished by Doctor Gurley, who attached the label "*Dendrograptus ontariensis*, type" to the specimen here figured, neither description nor figure could be found among his manuscript pages.



FIG. 12.—DENDROGRAPTUS ONTARIOENSIS, NEW SPECIES. VIEW OF THE MOST COMPLETE SPECIMEN. (SEE ALSO PL. 1, FIG. 4.) (BY R. S. BASSLER.)

Dendrograptus ontarioensis is evidently closely related to *D. prae-gracilis* Spencer, from which, however, it may be distinguished by its more regular, erect growth, and by its dichotomously dividing, rigid branches. Comparison of the figures of these respective species will show other differences, but it is believed that those mentioned will suffice for the recognition of this new form.

Horizon and locality.—This species is based upon a single rather complete specimen in the collection of the Chicago University, from the Niagaran dolomites at Hamilton, Ontario. Several fragmentary specimens in the collection of the U. S. National Museum agree with the type in all essential respects.

Holotype.—No. 13506, Walker Museum, University of Chicago.

Genus CALLOGRAPTUS Hall.

Callograptus HALL, Geol. Surv. Canada, Decade 2, 1865, p. 133; 20th Rep. New York State Cab. Hist., 1868, p. 218 (rev. ed., 1868 [1870], p. 252).—HOPKINSON, Ann. and Mag. Nat. Hist. (4), X, 1872, p. 233.—SPENCER, Can. Nat., VIII, 1878, pp. 458–462.—ZITTEL, Handbuch d. Pal., I, 1879, p. 289.—SPENCER, Can. Nat., X, 1882, p. 165; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 562, 570; Bull. Mus. Univ. State Missouri, I, 1884, p. 20.—MILLER, North Amer. Geol. and Pal., 1889, p. 175.—POCTA, Syst. Sil. Centre Boheme, VIII, Pt. 1, 1894, p. 179.—MATTHEW, Trans. New York Acad. Sci., XIV, 1895, p. 271, pl. 48, fig. 5.—GURLEY, Journ. Geol. IV, 1896, pp. 93, 308.—ROEMER and FRECH, Leth. geog., I. Theil, Leth. Pal., I, 3 Lief., 1897, p. 576.—RUEDEMANN, New York State Mus., Mem. 7, 1904, p. 583.

Callograptus NICHOLSON, Mon. Brit. Graptolithidæ, 1872, p. 128.

Gurley's manuscript contains quotations from many of the papers cited above, but no original notes are included. The following quo-

tation from Ruedemann's discussion of the genus^a will suffice for its recognition.

Hall based his genus mainly on its mode of branching and the resulting aspect of the rhabdosome; stating that it has "numerous slender bifurcating branches proceeding from a strong stem or axis," and that in its aspect it is intermediate between *Dictyonema* and some forms of *Dendrograptus*; that the branches are sometimes distantly and irregularly united by transverse dissepiments, but that the frond has not the regular reticulate structure of *Dictyonema* and differs from *Dendrograptus* in the mode of branching and the form of the thecae.

Genotype.—*Callograptus elegans* Hall. Tetragraptus zone of Quebec group, Gros Maule, Canada.

CALLOGRAPTUS MULTICAULIS Spencer.

Text figure 14.

Callograptus (Dendrograptus) multicaulis SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*.

Callograptus multicaulis SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, p. 572, pl. 1, fig. 11; Bull. Mus. Univ. State Missouri, I, 1884, p. 22, pl. 1, fig. 11.—GURLEY, Journ. Geol., IV, 1896, pp. 93, 308.

The original description is as follows:

Frond flabellate, possibly funnel-shaped in its growing state; branches, with two or three bifurcations, strong and somewhat numerous. Surfaces deeply striated longitudinally. The branches radiate from a common radicle until they occupy three-fourths of a circle; but whether they extended all around, and the frond grew in a funnel shape, can not be determined, as the lower branchlets are crushed and obscured. This beautiful little fossil has about a dozen principal branches well preserved, and these are about half a millimeter broad, with rather greater space between. The length of each branch is slightly over a centimeter, and the breadth of the frond about double that measurement. Cells are not known.

Formation and locality.—This graceful fossil was obtained from a more shaly bed of dolomite below the "chert bed" in the Niagara formation, at the "Jolly-cut road," Hamilton, Ontario.

No additional specimens of this species have been noted in the various collections studied.

CALLOGRAPTUS NIAGARENSIS Spencer.

Text figure 15.

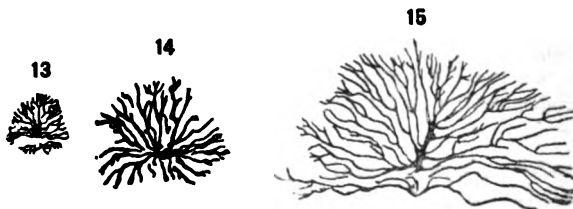
Callograptus niagarensis SPENCER, Canadian Nat., VIII, 1878, pp. 458, 463; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 571, pl. 1, fig. 9; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 21, pl. 1, fig. 9.—MILLER, North Amer. Geol. and Pal., 1889, p. 175, fig. 141.—GURLEY, Journ. Geol., IV, 1896, pp. 93, 308.

Doctor Spencer's original description is as follows:

Frond flabellate; the slender bifurcating branches more or less parallel, with occasional transverse filaments. The form is nearly semicircular with the

^a New York State Museum, Memoir 7, 1904, p. 583.

branches radiating from a common axis. In texture it is corneous, and the surface of the numerous flattened branches is marked with striations, appearing like oval impressions, while on the under side there are minute pits indicating the apertures of the cells, as many as twenty pits being visible in one-fourth of an inch. The fronds are usually less than 2 inches in breadth, and resemble



FIGS. 13-15.—13, *CALLOGRAPTUS MINUTUS* SPENCER; 14, *C. MULTICAULIS* SPENCER; 15, *C. NIAGARENSIS* SPENCER. (AFTER SPENCER.)

the outline of a bush, where the branches principally originate from the root.

This species is easily distinguished from *Dictyonema* by the bushlike form and more slender branches, together with an almost entire absence of dissepiments and

cell markings. In the better preserved specimens the cells readily distinguish it from *Dendrograpsus*, as also the more numerous and more parallel branches. The branches are broader, more drooping, and further separated than in the species of this genus found in the Quebec group.

Formation and locality.—This species occurs in the Niagara dolomites and shales at Hamilton, Ontario.

Gurley notes the following concerning the species, which is known only from the type, now destroyed:

The description of 1884 contains several statements requiring separate notice. The pits indicating the thecal apertures are stated to be "as many as 12 in a centimeter," a number amounting to 30 in an inch (25 mm.), as contrasted with 80. The longer diameter of the aperture is about 0.5 mm.

The frond does not usually exceed 4 cm. in breadth, being broader than high. The branches are a little less than 0.5 mm. broad, with spaces between them sometimes exceeding 1 mm.

CALLOGRAPTUS MINUTUS Spencer.

Text figure 13.

Callograptus minutus SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 572, pl. 1, fig. 12; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 22, pl. 1, fig. 12.—GURLEY, Journ. Geol., IV, 1896, pp. 93, 308.

The original description is as follows:

Frond orbicular. Branches, with one or two bifurcations, regularly diverging from the initial point like the venations of a palm leaf; they are all free. The surfaces are striated. The branches do not exceed one-fifth of a millimeter in breadth and are about half a millimeter apart. The whole height of the frond is a centimeter and the greatest breadth somewhat less.

Formation and locality.—This species occurs in the Niagara dolomite at Hamilton, Ontario.

No additional typical forms of this species have been found. Four specimens, three of which are fragmentary, furnish the basis for the description of the following variety.

CALLOGRAPTUS MINUTUS ALTUS Gurley, new variety.

Text figure 16.

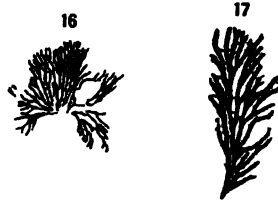
Doctor Gurley's description and notes are as follows:

Polypary as compressed (originally?), somewhat semicircular, consisting of branches about 0.2 mm. in width, bifurcating 2 to 4 times in their course toward the periphery, set about 45-50 in 25 mm. of width. Thecae invisible. Dissepiments very slender, apparently not numerous (too few visible to measure distances).

This form seems nearly allied to Spencer's *C. minutus*, but has a larger polypary (16 mm. high). Further, while agreeing fairly well with his description of *C. minutus*, it is not so easy to approximate it absolutely to his figure. Still it is possible that with more material this variety may be suppressed.

Horizon and locality.—The variety is based on two specimens (including the figured type) in the Spencer collection, from the Niagara chert, Hamilton, Ontario, and two additional specimens in the U. S. National Museum collections.

Cotypes.—Cat. No. 55311, U.S.N.M.



FIGS. 16, 17.—16, *CALLOGRAPTUS MINUTUS ALTUS*, NEW VARIETY. VIEW OF THE HOLOTYPE; 17, *C. STRICTUS*, NEW SPECIES. (SEE ALSO PL. 3, FIG. 3.)

CALLOGRAPTUS STRICTUS Gurley, new species.

Text figure 17. Plate 3, figure 3.

This new species is based upon a single, well-preserved specimen in the collection of the University of Chicago. Doctor Gurley's description is as follows:

Branches straight or very slightly flexuous, 0.4-0.6 mm. wide, bifurcating at frequent intervals (1 to 4 mm.); longitudinally striated by chitinous threads; set 20-25 in 25 mm. Thecae present, flattened against the branches, but obscure; apparently about 35-40 in 25 mm. Dissepiments few (at least few are preserved) and remote.

Horizon and locality.—Niagaran (Blue Building beds of section), Hamilton, Ontario.

Holotype.—Walker Museum, University of Chicago, No. 13513.

Genus *PTILOGRAPTUS* Hall.

Ptilograptus HALL., Geol. Surv. Canada, Decade 2, 1885, p. 139; 20th Rep. New York State Cab. Hist., 1868, p. 218 (rev. ed., 1868 [1870], p. 252).—ZITTEL, Handbuch d. Pal., I, 1879, p. 289.—SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 563, 591; Bull. Mus. Univ. State Missouri, I, 1884, p. 41.—MILLER, North Amer. Geol. and Pal., 1889, p. 201.—POCTA, Syst. Sil. Centre Boheme, VIII, Pt. 1, 1894, p. 201.—WIMAN, Natural Science, IX, 1896, p. 246.—ROEMER and FRECH, Leth. geog., I Thell, Leth. Pal., I, 3 Lief., 1897, p. 579.—RUEDEMANN, New York State Mus., Mem. 7, 1904, p. 587.

Ptilograptus NICHOLSON, Ann. and Mag. Nat. Hist. (4), I, 1868, p. 239; Mon. Brit. Graptolittidæ, 1872, p. 126.

The generic characters of *Ptilograptus* were given by Hall (1865) as follows:

Frond plantlike, rooted? simple or branching. Branches and branchlets plumose, the pinnules rising alternately on opposite sides of the branches: celluliferous on one face only; branches cylindrical or flattened. Substance corneous, dense; apparently smooth exteriorly, or corrugated by compression or during fossilization.

Genotype.—*Ptilograptus plumosus* Hall. Tetragraptus zone of Quebec group in Canada.

PTILOGRAPTUS FOLIACEUS Spencer.

Ptilograptus foliaceus SPENCER, Canadian Nat., VIII, 1878, pp. 458, 462.

Ptilograptus foliaceus SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 565, 591, pl. 6, fig. 7; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 41, pl. 6, fig. 7.—MILLER, North Amer. Geol. and Pal., 1889, p. 201, fig. 210.—GURLEY, Journ. Geol., IV, 1896, pp. 100, 309.

The original description is as follows:

Frond bipinnately branching. The slender branches are plumose, with delicate pinnules rising alternately from the opposite sides of the branchlets. There are angular openings on one side of the pinnules, whilst on the other there are indistinct corrugations. When viewed from the face, the cellules appear as oval impressions.

The branches seldom exceed more than half an inch in length and all appear to originate from nearly the same place on the axis. From these numerous parallel pinnules occur on each side of the axis (sometimes as many as sixteen). The pinnules seldom exceed the fourth of an inch [5 mm; 1884] in length and rise at a very acute angle [by the pinnules being regularly arranged; 1884]. Even if separate branches be found they are easily recognized. They appear to have been

attached, but from the specimens before me the radicle seems to have been broken off.

Like the other members of this group the texture is corneous, but sometimes replaced by pyrites. This species closely resembles the *P. plumulosa* of the Quebec group, but is smaller (three-fourths of an inch) and finer in structure with the relatively [fewer and; 1884] longer pinnules.

It occurs in the Niagara limestone at Hamilton, Ontario.



FIG. 18.—*PTILOGRAPTUS FOLIACEUS* SPENCER. THE TYPE-SPECIMEN AND A BRANCH ENLARGED. (AFTER SPENCER.)

The following notes are by Doctor Gurley:

The description of 1884 adds that there are usually three or four branches originating from near the same place on the short stipe, giving a lobed appearance to the frond. The branches are rather more than 1 cm. long. The cells occur on the lower sides of the branchlets (or pinnules). In 1 mm. there are 2 cells and 2 intercellular spaces. The slender branchlets are about 0.33 mm. thick, and the whole frond is never more than 2 cm. wide.

One specimen occurs, so labeled, in the Spencer collection, from the Niagara dolomite, Hamilton, Ontario. After close study of it, I have concluded that it is too obscure to add much to existing data, which amply suffice for the recognition of the species in Hamilton collections. I find the branches about 0.25 to 0.3 mm. wide, and the thecae 50 to 55 in 25 mm. Whether or not the generic reference is correct, it is the most natural provisional one, and may stand, pending better material.

Genus DICTYONEMA Hall.

Dictyonema HALL, Amer. Journ. Sci. (2), XI, 1851, p. 401; Nat. Hist. New York, Pal., II, 1852, p. 174.—PICTET, Traite de Pal., 2d ed., IV, 1857, p. 171.—HALL, Geol. Surv. Canada, Rep. Progr. for 1857, 1858, p. 142; Canadian Nat. Geol., III, 1858, p. 174; Nat. Hist. New York, Pal., III, 1859 [1861], p. 15; Geol. Surv. Canada, Decade 2, 1865, p. 136.—SALTER, Mem. Geol. Surv. Great Britain, III, 1866, p. 331 (2d ed., 1881, p. 535).—HALL, 20th Rep. New York State Cab. Hist., 1868, p. 218 (rev. ed., 1868 [1870], p. 252).—NICHOLSON, Mon. Brit. Graptolitidae, 1872, p. 129.—DAMES, Zeits. d. d. geol. Gesell., XXV, 1873, p. 383.—ZITTEL, Handbuch d. Pal., I, 1879, p. 289.—SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 562, 572; Bull. Mus. Univ. State Missouri, I, 1884, p. 22.—MILLER, North Amer. Geol. and Pal., 1889, p. 185.—HOLM, Bihang till K. Sv. Vet.-Akad. Handl., XVI, Afd. IV, No. 7, 1890, p. 4.—MOBERG, Geol. Foren. Stockholm Forhandl., XIII, 1891, p. 216.—MATTHEW, Trans. Royal Soc. Canada, IX, sect. IV, 1892, p. 33.—JAMES, Journ. Cincinnati Soc. Nat. Hist., XIV, Pt. 2, 1892, p. 153.—MOBERG, Geol. Foren. Stockholm Forhandl., XVI, 1894, p. 236.—TORNQUIST, Geol. Foren. Stockholm Forhandl., XVI, 1894, p. 380.—POCTA, Syst. Sil. Centre Boheme, VIII, Pt. 1, 1894, p. 190.—PRITCHARD, Proc. Royal Soc. Victoria, new ser., VII, 1895, p. 27.—WIMAN, Natural Science, IX, 1896, p. 243.—KOKEN, Die Leitfossilien, 1896, p. 327.—GURLEY, Journ. Geol., IV, 1896, p. 81.—FRECH, Leth. geog., I Th., Leth. Pal., I, 3 Lief., 1897, p. 557.—ROEMER and FRECH, Leth. geog., I Th., Leth. Pal., I, 3 Lief., 1897, p. 569.—WALTHER, Zeits. d. d. geol. Gesell., XLIX, 1897, pp. 250, 253.—GRABAU, Bull. Buffalo Soc. Nat. Sci., VI, 1899, p. 119; Bull. Buffalo Soc. Nat. Sci., VII, 1901, p. 133; Bull. New York State Mus., IX, 1901, p. 133.—RUEDEMANN, New York State Mus., Mem. 7, 1904, p. 591.

Dictyograptus HOPKINSON and LAPWORTH, Quart. Journ. Geol. Soc. London, XXXI, 1875, p. 667.—MOBERG, Geol. Foren. Stockholm Forhandl., XVI, 1894, p. 236.—TORNQUIST, Geol. Foren. Stockholm Forhandl., XVI, 1894, p. 380.

A very complete history of this genus (consisting of about forty pages of typewritten manuscript) was compiled by Doctor Gurley,

but a review and also a discussion of the generic characters was presented by Doctor Ruedemann before the Gurley manuscript came into his possession. To Doctor Ruedemann's excellent work the reader is referred.

Genotype.—*Dictyonema retiforme* (Hall). Niagaran (Rochester) shale, New York.

DICTYONEMA RETIFORME (Hall).

Gorgonia ? reteformis HALL, Rep. Surv. 4th Geol. Dist. New York, 1843, p. 115, text fig. 1.

Dictyonema retiformis HALL, Nat. Hist. New York, Pal., II, 1852, p. 174, pl. 40F, figs. 1 a, b.—LINCKLAEN, 14th Rep. New York State Cab. Nat. Hist., 1861, p. 55, pl. 7, fig. 1.—HALL, Geol. Surv. Canada, Decade 2, 1865, p. 12, fig. 10; 20th Rep. New York State Cab. Hist., 1868, p. 178, text fig. 11 (rev. ed., 1868, 1870, p. 210, text fig. 11).—NICHOLSON, Mon. Brit. Graptolittidæ, 1872, p. 129, text fig. 69.

Dictyonema retiforme SPENCER, Can. Nat., X, 1882, p. 165; Trans. Acad. Sci. St. Louis, IV, 1884, p. 573, pl. 3, figs. 1, 2; Bull. Mus. Univ. State Missouri, I, 1884, p. 23, pl. 3, figs. 1, 2.—MILLER, North Amer. Geol. and Pal., 1889, p. 185, text fig. 168.—POCTA, Syst. Sil. Centre Boheme, VIII, 1894, p. 192.—GURLEY, Journ. Geol., IV, 1896, pp. 96, 308.—ROEMER and FRECH, Leth. geog., I Th., Leth. Pal., I, 3 Lief., 1897, p. 575, text fig. 145.—GRABAU, Bull. New York State Mus., IX, 1901, pp. 133, 134, text fig. 27; Bull. Buffalo Soc. Nat. Sci., VII, 1901, p. 133, text fig. 27.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 155, text fig. 64.

This fine species, the genotype of *Dictyonema*, is a well-known although rather rare form in the Niagaran (Rochester) shale of New York. In Canada the species is confined to the earthy dolomites and shales beneath the chert bed of the more typical dolomites. Doctor Gurley has prepared the following redescription, based upon the types and other specimens studied by him:

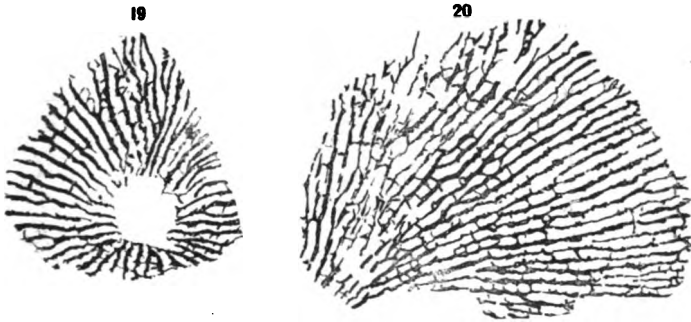
Polypary rather strongly radiate, with the branches usually about 0.8 mm. wide (a few as narrow as 0.6 mm., a few swelling out to 1 mm., particularly immediately below a bifurcation); about 15–17 in 25 mm. of width in the basal portion, and in young specimens frequently somewhat more slender, more tortuous (with slight tendency to zigzag) and somewhat farther apart; the interspaces consequently as wide as, or slightly wider than, the branches. Dissepiments mostly transverse (some are slightly oblique, a few very oblique); generally slender (about 0.2 mm.), but a few reach 0.3 mm., or rarely 0.4 mm. Meshes mostly oblong; a number of careful measurements has shown me that the most usual (the typical) length is on the average 1.5 mm. (between 1 and 2 mm.), but longer ones are seen, from covering up or destruction of the intervening dissepiments, which condition in favorable cases can be proven. \ Rarely two successive dissepiments are not farther apart than 0.5 mm. This almost invariably results from the two dissepiments diverging from a common point of origin on one branch.

Doctor Ruedemann has published the following on the species:

It is by no means so common in our Niagara beds as one should suspect from its long bibliographic list or conclude from the direct statement of some authors that it is abundant in the New York rocks; in fact, it is one of the least common of the graptolites of our Rochester shale and all the references are excerpts of Hall's original description. I have seen altogether not more than half a dozen specimens, including Hall's types, and have not been able to find one which would reveal the form of the thecæ.

Remarks.—*D. retiforme* is a remarkably stately graptolite, possessing wide-open, funnel-shaped rhabdosomes, fragmentary specimens of which with a diameter of no less than half a meter have been observed; and the size of the branches and the meshwork are coarse in proportion. Pocta has compared it to the Bohemian *D. grande* Barr[ande], also a Siluric form, and pointed out the differences between the two.

Horizon and locality.—The two specimens here figured are from the more shaly strata (beds 9–11 of section) beneath the cherty dolo-



FIGS. 19, 20.—*DICTYONEMA RETIFORME* HALL. A SMALL RHABDOSOME SHOWING THE CENTRAL PORTION AND A PORTION OF A LARGER SPECIMEN.

mite at Hamilton, Ontario. Both specimens are in the Spencer collection. The types of the species are in the American Museum of Natural History.

***DICTYONEMA CRASSIBASALE* Gurley, new species.**

Plate 3, figure 1.

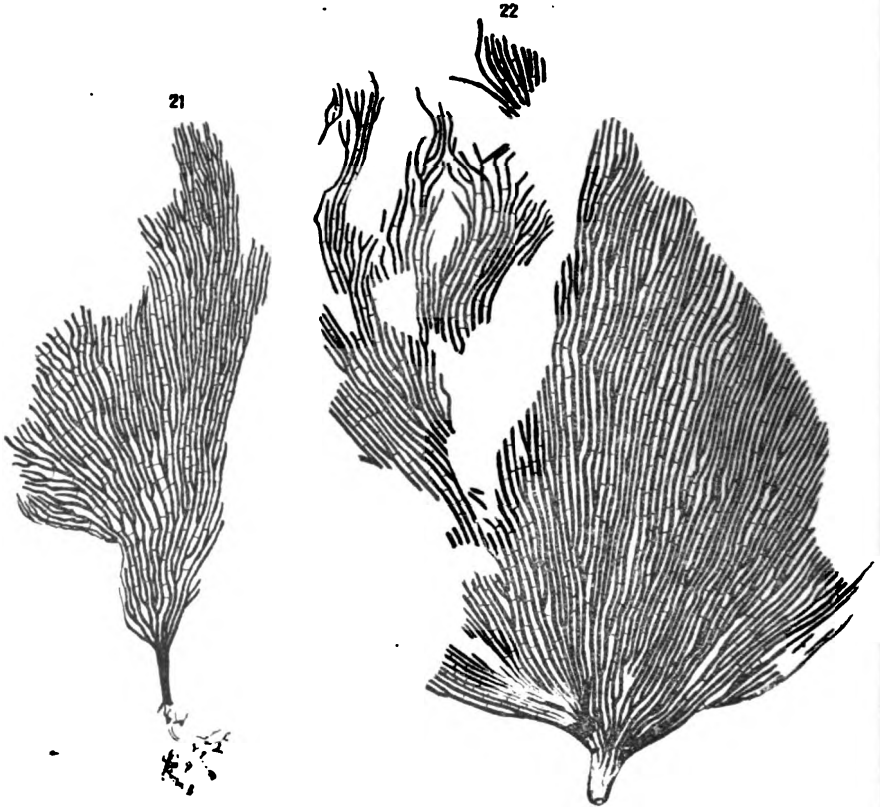
Dictyonema gracilis SPENCER (not HALL), Canadian Nat., VIII, 1878, p. 458; X, 1882, p. 165.

Dictyonema gracile SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 573, 574, pl. 2, figs. 2, 3; Bull. Mus. Univ. State Missouri, I, 1884, p. 24, pl. 2, figs. 2, 2a, 3.

This abundant species has hitherto been identified in the Hamilton collections as *Dictyonema gracile* Hall, but close comparison with Hall's types led Doctor Gurley to propose the above new name.

After quoting Hall's description of *D. gracile*, Spencer says of the present form:

In this species the branches are much more slender than in *D. retiforme*, averaging about half a millimeter in breadth and twice that distance apart. The branches are regularly arranged and form fan-shaped fronds, but many specimens indicate the cyathiform structure while living. Though the margins are generally even, yet in one fine specimen the terminations of the branches are irregular. The fronds converge to what is evidently a noncelluliferous radicle, and in size the finest specimens are as much as 10 cm. high and 6.5 broad.



FIGS. 21, 22.—*Dictyonema crassibasale*, new species. TWO RATHER SMALL RHIZOMES SHOWING THE PROXIMAL PORTION.

The transverse filaments, which are noncelluliferous, are from four to five times as far apart (sometimes much farther) as the branches; or are frequently obliterated, or almost so. The texture is corneous.

The celluliferous structure is shown in very few specimens. However, one specimen in particular, which I obtained from Mr. A. E. Walker, of Hamilton, removes all doubt as to the character of the cellules. On one side of the branch there is a slender solid axis, in the other there are inserted cylindrical calyces which penetrate the common canal (or cœnosarc) almost to the axis. The cells have their own distinct cell walls; they are cylindrical in form, about 0.5 mm. long and 0.35 mm. in diameter. The portion of the cell towards the orifice

overlies the base of the next cell, so that there are from 25 to 32 calyces in the length of a centimeter. More frequently only circular, or ellipsoid, elevated (sometimes depressed) points mark the former abodes of the polypites, which, being surrounded by a denser texture, have not yielded to the pressure which has flattened the walls of the common canal. The irregular striae and depressions on the stipes and branches are probably occasioned by the unequal flattening of the canal and celluliferous portions of stipes.

This species is the most easily obtained of the fossils of the group, though good specimens are very uncommon. Generally we must identify them by the relative size and arrangements of the branches and filaments, or, in more perfect specimens, by the form of the frond.

Doctor Gurley described *D. crassibasale* as follows:

Polypary, sometimes attaining a great size (one specimen indicates a diameter for the whole polypary of nearly half a meter), usually, however, of more

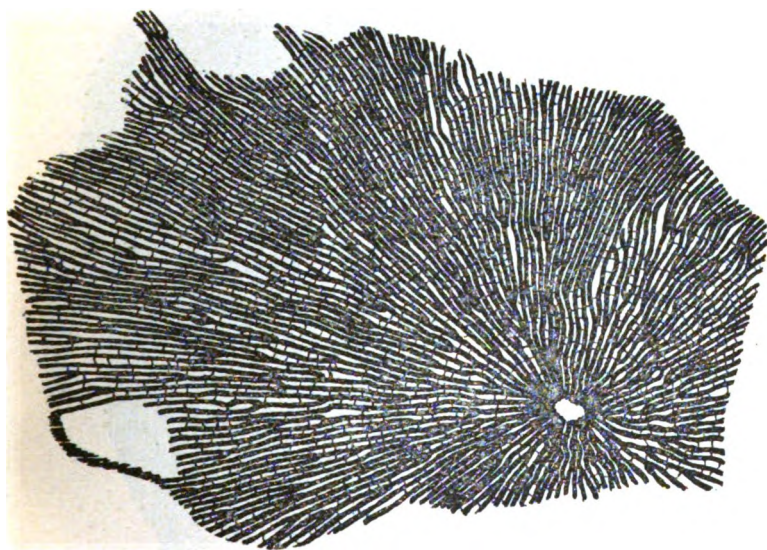


FIG. 23.—*DICTYONEMA CRASSIBASALE*, NEW SPECIES. A COMPRESSED INFUNDIBULIFORM RHABDOSOME.

moderate dimensions, cyathiform, consisting of parallel branches which radiate almost straight outward, but which are slightly flexuous in portions of their course. Their typical width is 0.5–0.6 mm. Some, however, especially distally, are as narrow as 0.4, and a few of the basal branches reach 0.8 mm. The branches are set 25–30 in 25 mm. of width, the number tending to reach the lower figure proximally and the higher figure distally. Distally, also, especially in fragments of large polyparies, the branches are sometimes as many as 35 in 25 mm., but not, I believe, except where distortion has occurred, perhaps from the dissepiments being more delicate in the younger portions of the polypary, or from greater post-mortem dissociation of the more flexible distal portion. Distally, too, the branches not infrequently, even in a normal polypary, will be seen to be quite tortuous and the meshes more irregular. Bifurcations occur at irregular and increasingly longer intervals. They are U-shaped, their sides often tending to bow outward and then to approach each other above. It is

especially around the bifurcations that the meshwork tends to depart from regularity and the branches to become flexuous. The dissepiments are all very slender, and are very numerous. They are all transverse or only very slightly oblique. Most of them are 1 mm. apart, though on a general average there may probably be as few as 20 in 25 mm. The greatest distance between consecutive dissepiments seems about 1.5 mm. Occasionally two may be very



FIG. 24.—*Dictyonema crassirachale*, new species. A COMPRESSED, FRAGMENTARY RHADROME.

close together (0.4 mm.). Of course, being so very slender and the branches being comparatively stout, it often happens that an apparently well-preserved polypary may show the branches well preserved though the dissepiments have suffered. The meshes are rectangular, except where flexuosity of the branches renders them irregular. The thecae, or rather indications of them in the form of oval elevations, are frequently well preserved, so frequently and so well

that this feature serves, in Hamilton collections, as a rather good mark of the species. They are about 55-60 in 25 mm.

Horizon and locality.—By far the most common species of the genus in the chert-dolomite series at Hamilton, Ontario. I count 38 specimens, which include only a few (selected from many) in the Hall and New York State collections; also one in the Spencer collection labeled "*Dictyonema gracile*."

In normal polyparies this species is easily distinguished from *D. gracile*. Its most characteristic features are the fibrous root, the heavier polypary, especially the much heavier branches at the base, the much more numerous dissepiments, and the fewer branches in 25 mm. of width, and (in Hamilton collections) the often well-preserved thecal elevations. Distal fragments of the two species (which, moreover, are rather more apt to be worn) are not always so easy to separate; but those of the present species are apt to be very extensive and



FIG. 25.—*Dictyonema crassibasale*, new species. RHABDOSOME PRESERVING THE FIBROUS PROXIMAL PORTION AND SHOWING THE THECÆ, $\times 1.5$.

somewhere to yield characteristic marks. Usually, of course, they are to be identified by comparison with more perfect specimens.

The species to which this is most closely related is certainly *D. splendens*. Of that species I have but one specimen, so that I am unable to determine what range of variation it may present. Of the present one, however, I have nearly forty specimens, and with no one of them could I consider Billing's specimen as conspecific.

After a careful study I am convinced that this is the species which Spencer describes as *D. gracile* Hall. I base this opinion on his figures, particularly figure 3, the thecæ in which could, as far as the material before me goes, only belong to this species; and on his statements that it has a "noncelluliferous radicle," and that it is the species most easily obtained. Indeed, this species may be known in Hamilton collections by its very great frequency, it being by far the most common species.

Cotypes.—Cat. No. 55297, U.S.N.M.; Nos. 13502, 13504, Walker Museum, University of Chicago.

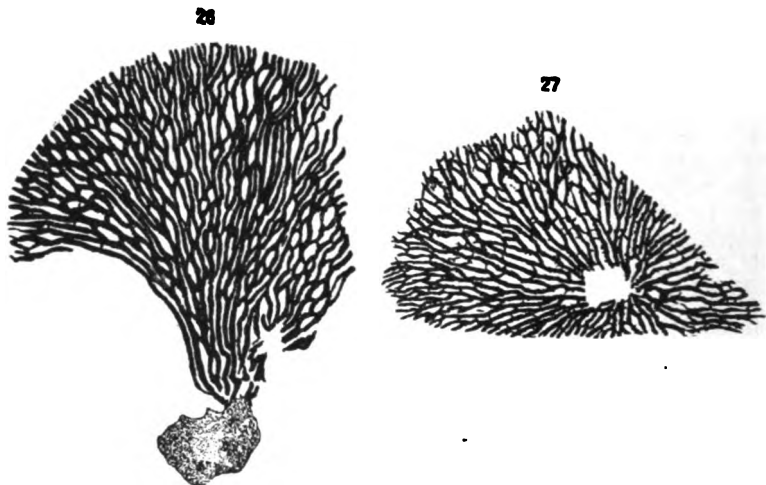
DICTYONEMA POLYMORPHUM Gurley.

Plate 4, figure 4.

Dictyonema tenellum SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pl. 1, fig. 13 (not the description, p. 576); Bull. Mus. Univ. State Missouri, I, pl. 1, fig. 13 (not the description, p. 26).

Calyptragraptus subretiformis (part) SPENCER, Trans. Acad. Sci. St. Louis, IV, pl. 4, fig. 2; Bull. Mus. Univ. State Missouri, I, 1884, pl. 4, fig. 2.

Dictyonema polymorphum Gurley Ms., RUEDEMANN, New York State Mus. Mem. 11, 1908, p. 158, pl. 2, fig. 3; pl. 3, figs. 4, 5, 6; p. 160, text figs. 60-72.



FIGS. 26, 27.—*DICTYONEMA POLYMORPHUM* GURLEY. 26, RHADOSOME RETAINING DISK (PLESIOTYPE); 27, A COMPRESSED SPECIMEN (HOLOTYPE) WITH CENTRAL PORTION. (SEE ALSO PL. 4, FIG. 4.)

Doctor Gurley's elaborate description of this species has been published by Ruedemann,^a but is repeated here for the sake of completeness:

Polypary originally cyathiform, circular or flabellate on the rock, when flabellate often evenly semicircular in the largest specimen seen, 85 mm. in diameter; originating in and sessile upon a carbonaceous "disk," which in one specimen is seen to have its walls riddled with pores. Branches measuring 0.6 mm. in width on the average, hardly ever as narrow as 0.3 mm. (as Spencer states them to average), 0.4 mm. being, with rare exceptions, the minimum and 0.8 the maximum. Branches varying equally in character, being sometimes nearly straight, at others irregularly sinuous, and inosculating, as in *Desmograptus*. Occasionally the adjacent margins of two branches coalesce. The branches end in long drawn out, spike-like points. Very often—usually, in fact—shortly before their termination, they bifurcate, U like, the termina-

^a New York State Mus., Memoir 11, 1908, p. 158.

tion thus being forcepslike. This mode of ending is quite characteristic of the species. Apparently this spike-like forking of the branches may occasionally take place in the wall of the polypary below the summit, and the spikes then seem to serve the same purpose as dissepiments, bracing the polypary. As the fossil usually lies on the stone, the number of branches in 25 mm. of width is exceedingly variable, generally from distortion. In places where the polypary is evenly and smoothly laid out and the meshwork perfectly regular, however, the number is about 22 (20–25) near the base and about 25–30 at the periphery. The dissepiments are of medium thickness (about 0.15–0.4 mm.) and are either perpendicular or highly inclined (say 45°) to the branches, and this combination in the same specimen forms a striking feature of this species, a feature well shown in Spencer's figure (text fig. 29). Meshes very variable in shape, corresponding to the irregularity in the branches and dissepiments. In one specimen I find meshes from 1.5 to 6 mm. long, but the longest are in one or two cases demonstrably subdivided, and probably 3 mm. is about the greatest length. From obscure indications the thecae seem to be set about 50 in 25 mm. (Spencer gives the number as 60.)

One specimen (text fig. 26) in the Hall collection shows the base fairly well preserved. This measures about 12 by 8 mm. and shows a unique structure. The margin is in places sharply defined, and is either convex or concave. The surface is uniformly dotted with very numerous elliptic or circular pores, which hardly reach 0.2 mm. in the greatest diameter, and which have a well-defined rim-like margin. They seem to have a somewhat regular arrangement, in rows and are separated by interspaces narrower than their own diameter. The texture of this "disk," like that of the network, is carbonaceous.

Horizon and locality.—Twenty-four specimens from the Niagara chert and glaiated chert beds, Hamilton, Ontario.

In this count are included two specimens in the Spencer collection, labeled '*Calyptograptus subretiformis*.' While these two specimens are very poor, still without question they belong here and not with *C. subretiformis*. On the other hand, it is quite evident to me that these two specimens are of the species which furnished the basis for Spencer's figure 2, which differs considerably from his figure 1, and his figure 2 should, therefore, I believe, be added to the synonymy of *D. tenellum*.

This species is exceedingly variable in appearance. It is sometimes spread out circularly, sometimes flattened flabelliformly from the side. Its most characteristic features are the average thickness of 0.6 mm. (not 0.3 mm., as Spencer's text states), their number of 20–25 in 25 mm. of width in the proximal and of 25–30 in the distal portion of the polypary. But in this species, more than in others, it is possible to get almost any number, unless the place for counting be carefully chosen, where the meshes are regularly laid down and not distorted. Further, the combination in the same specimen of transverse dissepiments and of dissepiments inclined at about 45° to the branches, with,

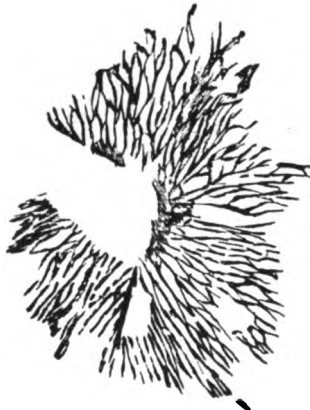


FIG. 28.—*Dictyonema polymorphum* GURLEY. ONE OF SPENCER'S TYPES OF *CALYPTOGRAPTUS SUBRETIFORMIS*. (AFTER SPENCER.)

In other places, modes of connection (coalescence of approximated lateral margins, curving together and entire fusion of adjacent branches) usual in *Demograptus*, thus producing a great variety of mesh form, constitutes a striking feature in the present species.

This species is one of the most common graptolites in the Rochester shale of New York, as well as in the limestone at Hamilton, Ontario. Quoting Doctor Ruedemann:

This form is easily distinguished from both its associated congeners, *D. retiforme* and *D. gracile*, by its more irregularly bent branches and the oblique direction of the dissepiments. By these characters it seems to lead directly to *Calyptragraptus subretiformis* Spencer with which it is also associated.

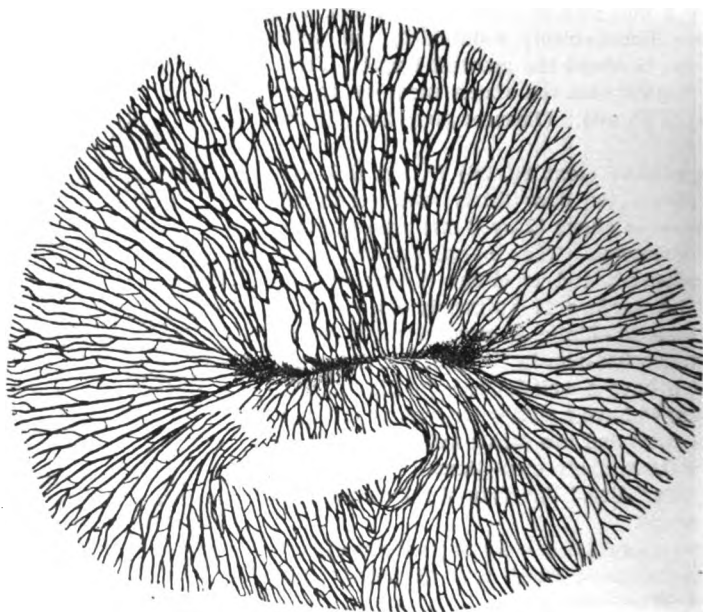


FIG. 29.—*Dictyonema polymorphum* GURLEY. SPENCER'S FIGURED TYPE OF *Dictyonema tenellum*. (AFTER SPENCER.)

Holotype (selected by Ruedemann).—Cat. No. 54278, U.S.N.M.

Plesiotype.—Walker Museum, University of Chicago, No. 13517.

Dictyonema subretiforme (Spencer).

Calyptragraptus subretiformis SPENCER, Canadian Nat., VIII, 1878, pp. 453, 460.

Calyptragraptus subretiformis SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, p. 578, pl. 4, fig. 1 (not fig. 2); Bull. Mus. Univ. State Missouri, I, 1884, p. 28, pl. 4, fig. 1 (not fig. 2).

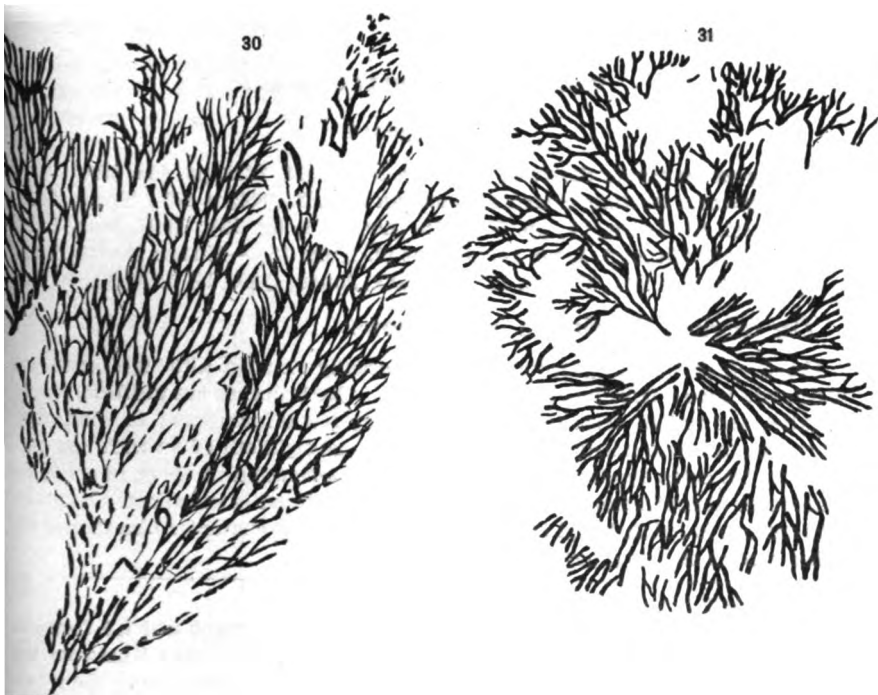
Dictyonema subretiforme RUDEMANN, New York State Mus., Mem. 11, 1908, p. 162, pl. 2, figs. 1, 2.

This species is closely related and similar to the preceding form, *D. polymorphum*, both of which have been described and illustrated by

Ruedemann. Spencer's original description, with additions from his description of 1884 contained in brackets, is given below :

Frond circular, but cyathiform in its growing state. There are numerous bifurcating branches, which in the fossil condition imperfectly unite or overlap each other, producing a kind of fine network with irregular sub-rhomboidal [ellipsoidal] interstices. In texture it is corneous, having the branches marked with striations of a sub-rhomboidal form.

In this species the branches are much finer (but little more than one-eightieth of an inch in width [0.35–0.75 mm.]) than in *C. cyathiformis*, with more numerous and irregular bifurcations, producing a netted appearance. The original matter is often replaced by pyrites. The fronds are not generally more than two inches



FIGS. 30, 31.—*Dictyonema subretiforme* (SPENCER). 30, ONE OF SPENCER'S TYPES OF *CALYPTOGRAPTUS SUBRETIFORMIS*. (AFTER SPENCER.) 31, A LARGE EXPANDED RHABDOSOME FROM THE ROCHESTER SHALES OF NEW YORK. (COPIED FROM RUEDEMANN.)

in diameter. Only a few specimens have been found, and these show some varietal differences.

This species was found in the Niagara limestone [principally in the shaly dolomites beneath the chert bed], Hamilton, Ontario, by Colonel Grant.

To this description Gurley adds the following :

Measurements of a number of branches show that these nearly all fall between 0.4 mm. and 0.6 mm., 0.4–0.5 being the dimensions usual in the distal portion for the branches exclusive of the terminal twigs. The more proximal stems measure 0.6 mm., and the thickest seen (in one specimen only) reached 0.8 mm. Corresponding to the straggling aspect of this species almost any number of branches may be counted transversely, but if portions be selected where the branches are

at fairly regular distances apart and the meshes consequently of pretty uniform width, the number will be found to be about 25 (say 23-27).

Ruedemann^a says, in connection with the generic position of the species:

As both Spencer's drawings and our material show, these [generic] characters are not retained in his second species, *C. subretiformis*. The latter clearly possesses dissepiments, which, however, are so oblique that they appear as bifurcations [see Spencer's figure, here copied.] *Dictyonema polymorphum* Gurley indicates transition from a typical *Dictyonema* with rectangular meshes to this irregularly meshed form. The clearly closer relationship of the present species to *Dictyonema polymorphum* than to *C. cyathiformis* has induced us to place it under the former genus and to restrict *Calyplograptus* to forms which retain the diagnostic characters of the genotype.

DICTYONEMA TENELLUM Spencer.

Plate 2, figure 4.

Dictyonema tenella SPENCER, Canadian Nat., VIII, 1878, pp. 458, 459.

Dictyonema tenellum SPENCER, Canadian Nat., X, 1882, p. 165; Trans. Acad. Sci. St. Louis, IV, pp. 564, 576 (not pl. 1, fig. 13); Bull. Mus. Univ. State Missouri, I, pp. 14, 26 (not pl. 1, fig. 13).—MILLER, North Amer. Geol. and Pal., 1889, p. 185.—GURLEY, Journ. Geol., IV, 1896, pp. 96, 308.

The original description is as follows:

Frond cyathiform in growing state, but usually circular, although occasional specimens have a flabellate form in the rock. The branches are uniform, nearly parallel, and radiate from the center with very few bifurcations; in width they vary from one one hundred and twentieth to one-eightieth of an inch, but uniform in the same specimen. The branches are connected at short intervals by transverse dissepiments; while the margin of the frond is remarkably constant. The surface is striated, and the texture has a corneous character like that of the other species of this group.^b

^a New York State Mus., Mem. 11, 1908, p. 164.

^b Here is interpolated in the description of 1884, a paragraph which I footnote, being convinced that with the exception of the statement that "between the branches there are not usually spaces as great as (or greater than) their own width," it has no reference to the species now under consideration.

"In the best specimens distinct ellipsoidal pits are arranged along the sides of the branches, marking the positions of the calyces, these having the longer diameter equal to half a millimeter and their shorter occupying two-thirds of the width of the stipe. There are about twenty-four of these calyces arranged longitudinally in the length of a centimeter. In specimens less perfectly preserved the bars connecting the branches are almost obliterated, and in those in a better state of preservation they are placed from 2 to 3 mm. apart, while between the branches there are not usually spaces as great as (or greater than) their own width."

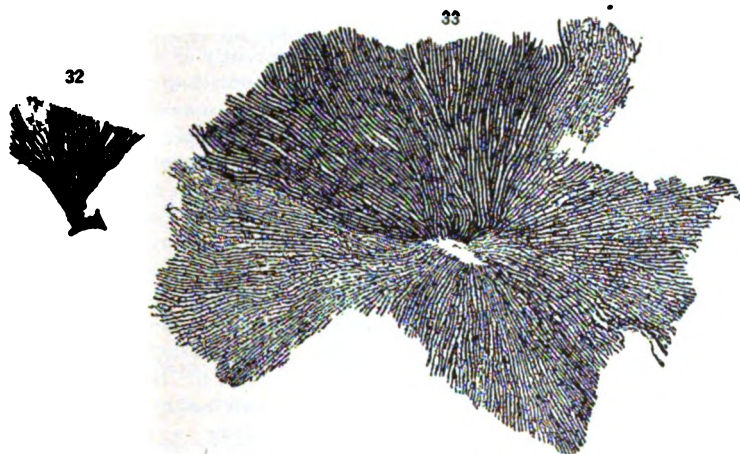
Respecting the species to which he does refer, I can only say that in my experience, *D. crassibasale* more usually than any other species, has the thecae preserved, and that those structures in *crassibasale* could be described in about the words used. But in no species could be both 0.5 mm. long, and 24 in 1 cm.—R. R. Gurley.

As the connecting filaments are very fine, owing to imperfect preservation, they are not always distinct over the whole surface of the frond. This species is easily distinguished from *D. gracilis*—even in fragments—by the branches being exceedingly fine (about one-hundredth of an inch in width), with scarcely that distance between them, and with no approach to the dendritic form of that species. The frond maintains its character even in the young state. The largest frond is three and one-half inches in diameter.

It occurs in the Niagara limestone [dolomitic limestones of the cherty beds and in the underlying more shaly rocks; 1884] at Hamilton, Ontario. The specimen described was obtained by Lieutenant-Colonel Graut, and presented to the writer.

Spencer's description of 1884 adds, that the dissepiments are very delicate, and the margin entire. He further says:

This species is easily distinguished from *D. gracile* [= *D. crassibasale* Gurley] by the branches being much finer, less diverging, and with more bifurcations, by the transverse bars being more closely arranged, and by the frond being



FIGS. 32, 33.—*DICTYONEMA TENELLUM* SPENCER. 32, A SMALL EXAMPLE PRESERVING THE BASAL PORTION. (BY R. S. BASSLER.) 33, A LARGER RHADOSOME.

regularly circular, with no general bush-like form like that seen in most specimens of *D. gracile* [*crassibasale*]. The largest frond is 9 cm. in diameter.

Gurley's description of the species is as follows:

Polypary cyathiform, in the flattened state radiating from a center; proximal extremity only indistinctly visible in one specimen (text fig. 32), appearing to consist of some kind of a bulbous or fibrous root. Branches straight, mostly 0.3–0.35 mm. wide; a few as narrow as 0.25; occasionally one as wide as and none wider than 0.4 mm. Number of branches transversely in 25 mm., proximally about 45, distally 50–55. Interspaces consequently rarely as wide as and usually much narrower than branches. Minimal length of meshes about 0.5 mm., maximum about 1 mm. Thecae invisible. Dissepimenta of about medium thickness, straight or oblique.

The identification of this species I consider thoroughly made out. There is no other species at Hamilton, at least in my experience, to which Spencer's original description could refer. But in 1884 Spencer figured as *D. tenellum* a

totally different species, the one I have named *D. polymorphum*. It is very important to note that his description, too, has become tinged with foreign elements, the whole of the second paragraph, with the possible exception of the statement that "between the branches there are not usually spaces as great as (or greater than) their own width," having no application to the present species.

Horizon and locality.—Not uncommon in the Niagara dolomite, chert, and glaciated chert at Hamilton, Ontario.

The originals of text figure 32 and Plate 2, figure 4, are in the National Museum, while the third figured specimen (fig. 33) belongs to the Spencer collection.

Plesiotypes.—Cat. No. 55300, U.S.N.M.

DICTYONEMA STENACTINOTUM Gurley, new species.

Plate 3, figure 2.

Gurley's description of this fine new species follows:

Polypary flabelliform, included within an angle of 35° , somewhat obscure at base; branches 0.6–0.8 mm. wide (in places apparently as narrow as 0.4 mm.,



FIGS. 34, 35.—*DICTYONEMA STENACTINOTUM*, NEW SPECIES. 34, HOLOTYPE. 35, A RHABDOSOME REFERRED SOMEWHAT DOUBTFULLY. (SEE ALSO PL. 3, FIG. 2.)

but they are there not fully exposed, as the same branches elsewhere show in their course the full width); mostly parallel, in places curving irregularly, causing distortion of the meshwork; set 17–18 in 25 mm. of width. Dissepiments slender or thick, several reaching 0.6 mm. and but for their position being virtually indistinguishable from a nearly transverse branch. The majority are transverse, though many are more or less and some are quite oblique. Most are parallel-sided; a number are triangular. In general the meshwork is regular, the meshes rectangular. The

most regular meshes vary in length between 1.5 and 2.5 mm. Distorted meshes may be as short as 0.5 mm., though more usually 1 mm. is the minimum. Only obscure indications of these are seen.

The above description refers to the type-specimen alone [fig. 34]. One other specimen [text fig. 35, Pl. 3, fig. 2], from approximately the same horizon, exhibits a general resemblance to the type, but with some differences. It may be described as follows:

Polypary known only in the form of a fragment of the meshwork; branches heavy (0.8 mm. wide), parallel, diverging only very slightly, bifurcating correspondingly rarely (the few successive bifurcations visible are 12–20 mm. apart); set 15 or 16 in 25 mm. of width. Dissepiments when unworn probably

always heavy (0.4, 0.6, 0.8 mm.), though as seen they are sometimes slender, usually transverse, sometimes oblique. Meshes coarse, rectangular, about 3 mm. or more in length, though occasionally one is seen as short as 1.5-2.5 mm. Apparently the length may reach 5 or even 6 mm., but in one mesh of this character two intermediate dissepiments can be made out on close observation. So that the superficial aspect of the fossil is not to be implicitly trusted.

Careful comparison with the three species (*websteri*, *retiforme*, *percrassus*) to which this form comes nearest, shows it to be distinct from all; from the last two it may be known by the absence of the rapid radiation of the polypary.

Horizon and locality.—Two specimens in National Museum, both from the Niagara dolomite, Hamilton, Ontario.

Holotype and paratype.—Cat. No. 55299, U.S.N.M.

DICTYONEMA EXPANSUM Spencer.

Dictyonema expansum SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 575, 576, pl. 2, fig. 1; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 25, 26, pl. 2, fig. 1.—GURLEY, Journ. Geol., IV, 1890, pp. 96, 308.

Spencer's original description is as follows:

Fronde flabelliform, composed of slender, expanding, and bifurcating branches, diffusely arranged, and united laterally by slender filaments (often wanting); branches irregularly striated; texture corneous.

This species is clearly related to *D. gracile* in the relative size of the branches, but these are much more diffusely and irregularly arranged, with greater interspaces, which are from two to four times the width of the branches. The transverse filaments occur less frequently than in *D. gracile*. Fragments of this species are not always easily distinguishable from *D. gracile*, although the branches are looser and more spreading. The type specimen is 8 cm. high and about 16 broad, rising from a united base of five or six stipes.

Formation and locality.—Niagara limestones at Hamilton, Ontario.

Doctor Gurley describes a specimen of this species as follows:

There is in all the Hamilton collections but one specimen which I could by any possibility refer to Spencer's *expansum*. It may be described as follows:

Polypary 120 mm. high and 235 mm. broad; flabelliformly compressed, semi-circular in outline, consisting proximately of eight parallel branches, and higher up of numerous branches, which are approximately straight (or with long, sweeping curves) and subparallel; the extreme lateral ones perpendicular to the median line of the polypary, nearly straight, the whole curvature occurring proximally in a short turn. Width of branches pretty uniformly 0.8 mm., one being occasionally seen 1 mm. wide. Distally the specimen is so worn that it is hard to say whether the full width is maintained to the periphery or not, but a few unworn branches there measure 0.8 mm. The branches are everywhere set about 17 in 25 mm. of width. Concerning the number of dissepiments, nothing can be said, the specimen being too much worn. No thecae are visible.

Horizon and locality.—One specimen in Spencer's collection, labeled *Dictyonema retiforme*, from the Niagara dolomite, Hamilton, Ontario.

I can not say that I feel entire confidence in the identification, but I think this is Spencer's species. As above remarked, it is the only one in the collections which could be *expansum*, and it agrees as well with Spencer's descrip-

tion, and particularly with his figure, as a poorly preserved specimen could be expected to. Parenthetically, I may say that it seems distinct from all the

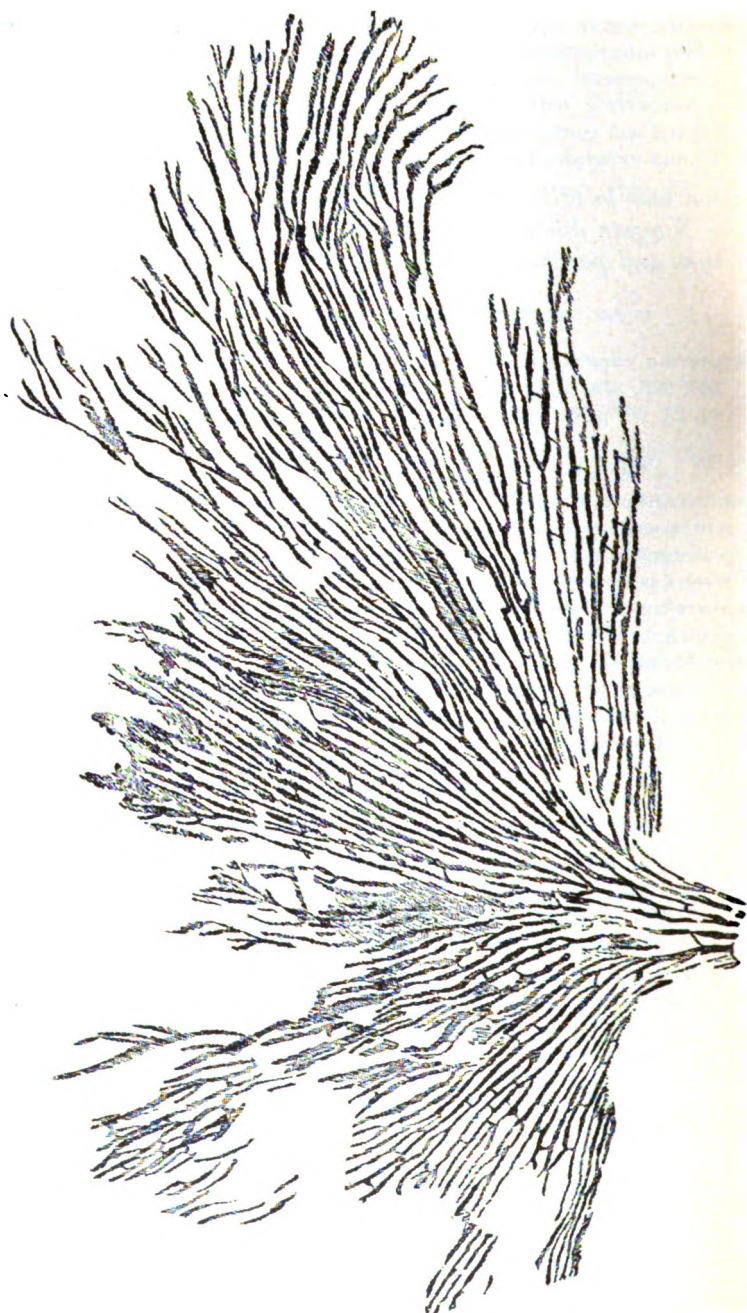


FIG. 30.—*Dictyonema expansum* SPENCER. THE ORIGINAL TYPE. (COPIED FROM SPENCER.)

other species at Hamilton. Among its distinctive marks may tentatively be named: The perpendicularity of the extreme lateral branches of the median

line of the polypary, and the restriction of the curvature of the branches within a short space toward their proximal end, the approximately straight course of

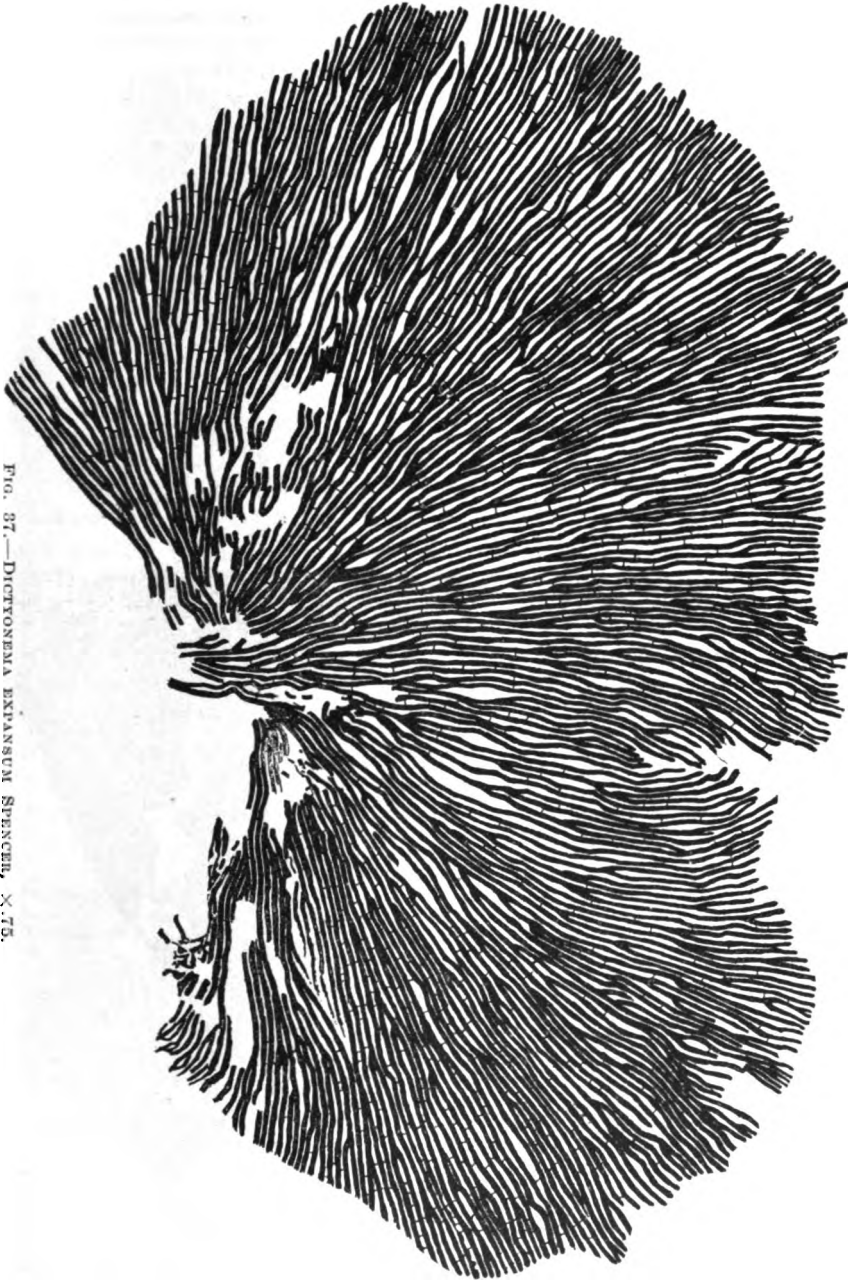


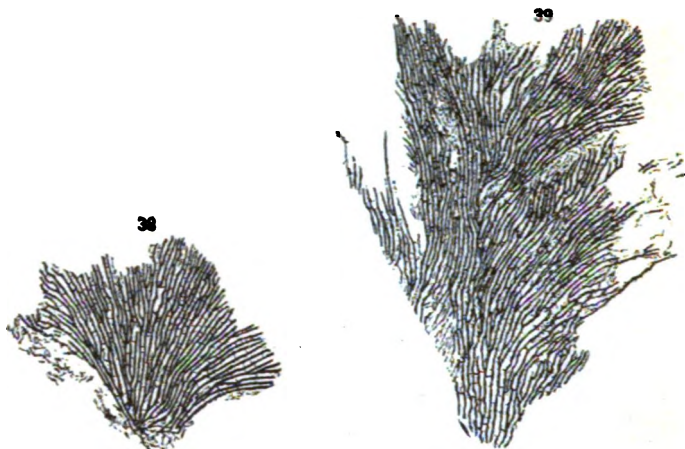
FIG. 37.—*Dictyonema expansum* SPENCER, X.75.

the branches, and lastly, of course, the measurements. According to Spencer, the dissepiments are fewer than in *D. crassibasale* (his *gracile*).

DICTYONEMA FILIRAMUS Gurley, new species.

Gurley's description of this species is as follows:

Polypary varying from flabelliformly compressed, nearly and regularly semi-circular, about 25–30 mm. in radius, to flabellate expansions 14 or more cm.



FIGS. 38, 39.—**DICTYONEMA FILIRAMUS**, NEW SPECIES. TWO SMALL RHABDOSOMES.

In diameter. Branches straight or uniformly curved, mostly 0.3 mm. wide, reaching 0.4 mm., especially near the base; set about 40 in 25 mm. (7–9 in 5 mm., the strong radiation preventing counting for longer distances.) Bifurcations narrow, tending to V-shape. Dissepiments exceedingly fine; rather uniformly 1 mm. apart, occasionally two as close together as 0.5 mm.; quite uniformly transverse. Meshes quite regular, rectangular. Too few thecae are visible to permit of any accurate estimate of their number, but they seem to be something like 100 or more in 25 mm.



FIG. 40.—**DICTYONEMA FILIRAMUS**, NEW SPECIES. A RHABDOSOME OF MEDIUM SIZE.

Horizon and locality.—

Not uncommon in the dolomite and chert at Hamilton, Ontario.

Cotypes.—Cat. No. 55303, U.S.N.M.

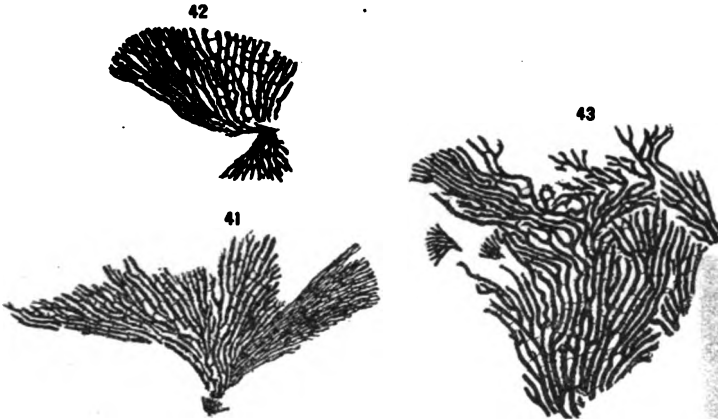
DICTYONEMA DESMOIDES Gurley, new species.

Plate 4, figure 3.

Gurley describes this species as follows:

Polypary cyathiform, flabelliformly compressed, tending to spread rather widely, with branches 0.5 mm. (0.4–0.6 mm.) wide, the central ones usually straight, or only slightly undulate, the lateral ones diverging moderately, or

sometimes extremely and often undulate or more or less tortuous, and really or apparently fusing *Desmograptus* fashion. In places where the meshwork is laid down evenly and without distortion there are about 30 branches in 25 mm. of width. Proximally the number may perhaps be somewhat less (say 27). Distally, especially laterally, where the branches are reflexed, and, in some places crowded, there may be 35 in 25 mm., a condition perhaps due to distortion. The interspaces then are, in general, narrower than the branches, and much narrower distero-laterally, where the latter are crowded. The dissepiments are heavy (0.2–0.4 mm. thick), and apparently somewhat remote, but the exact



FIGS. 41–43.—*Dictyonema desmoides*, new species. 41, THE HOLOTYPE, A SMALL BUT RATHER COMPLETE RHABDOSOME. (BY R. R. BASSLER.) (SEE ALSO PL. 4, FIG. 3); 42, 43, PARATYPES. TWO FRAGMENTARY RHABDOSOMES.

distance cannot be stated. Meshes rectangular, elliptic, or irregular. Thecae obscure, but apparently about 50 in 25 mm.

Horizon and locality.—Niagara chert, Hamilton, Ontario.

Holotype.—New York State Museum, Albany, New York.

Paratype.—Cat. No. 55304, U.S.N.M.

Dictyonema percrassus Gurley, new species.

Doctor Gurley's description is as follows:

Portion of the polypary seen (incomplete proximally) flabellate, radiating rather rapidly, the width increasing, in one specimen, in the longitudinal or radial distance of 30 mm. from 8.5 to 38 mm. and the branches from 7 to 21. The width thus increases more rapidly than the branches. The increased space is, however, taken up by the increased thickness of the branches, which, in proceeding from the base, rapidly increase to a width of about 0.8 mm. and at the periphery may reach 1 mm. Proximally a few are as narrow as 0.4 mm., but nearly all are 0.5 mm., and some measure 0.6 mm. Distally the interspaces are quite or very nearly as wide as the branches, but never wider. Proximally, however, they are about $1\frac{1}{2}$ times as wide as the branches or (with the narrowest branches) even a little more. Proximally the number



FIG. 44.—*Dictyonema percrassus*, new species. A FRAGMENTARY RHABDOSOME.

of branches is about 20 in 25 mm. of width. Distally it ranges from 14 to 17. The dissepiments are not very slender (reaching a width of 0.2 mm. *ad max.*), straight or oblique, sometimes two diverging from a common point of origin on the branch. Length of meshes probably (when all the dissepiments are preserved and visible) not much exceeding 2 mm. The dissepiments are, in many places, obscure, but seem usually to be 1.5–2.0 mm. apart. Smallest complete meshes about 1 mm. long. Branches obscurely striate. These invisible.

Horizon and locality.—Glaciated chert beds, Niagara formation, Hamilton, Ontario.

This species is characterized especially by the very great thickness of its branches, the general radiating aspect of the polypary, and the small number of branches transversely.



FIG. 45.—*Dictyonema percrassus*, new species. RHABDOSOME WITH BASAL ATTACHMENT.

Cotypes.—Collection of Walker Museum, University of Chicago, No. 13511; Spencer collection.

***Dictyonema spenceri* Gurley, new species.**

Plate 4, figure 1.

Doctor Gurley's description follows:

Polypary circular or flabelliform, consisting of heavy branches, mostly about 0.8 mm. wide, some as narrow as 0.6 mm., set about 17–20 in the proximal portion and usually about 20–22 in 25 mm. of width in the peripheral portion of the polypary, nearly straight, subparallel, with about 4 or 5 bifurcations in their course toward the periphery. Dissepiments usually slender, though an occasional one reaches 0.5 mm., usually 1.5–2 mm. apart, and in many cases a 3 mm. interval is seen without any trace of an intermediate dissepiment subdividing this long mesh. But in other cases similar long meshes are seen, on close inspection, to be subdivided by an intermediate dissepiment. Meshes subquadrangular.

Horizon and locality.—Five specimens from the Niagara chert, Hamilton, Ontario.

This species has the branches slightly thicker and somewhat more numerous than in *D. retiforme*, which it most resembles. It is therefore a closer form than *retiforme*, the interspaces usually tending to be narrower, or at least not wider than the branches, especially distally, where, on the contrary, in *D. retiforme*, the tendency is for the interspaces to be, relatively to the branches,



FIG. 46.—*Dictyonema spenceri*, new species. HOLOTYPE. (SEE ALSO PL. 4, FIG. 1.)

widest, this condition resulting from a tendency of its branches to spread too rapidly for bifurcation to keep pace with the spreading. This of course shows in the number of branches in 25 mm. of width, which at the periphery of *D. retiforme* tends to sink to say 15.

Holotype.—Cat. No. 55301, U.S.M.A.

Dictyonema parallelum Gurley, new species.

Plate 4, figure 2.

The description by Gurley is as follows:

Polypary originating from a fibrous root; consisting of rigid, wiry, parallel, little-diverging branches, mostly 0.4 mm. wide, but reaching 0.6 mm. in the proximal portion; set 35-40 transversely in 25 mm. Meshes correspondingly narrow, being usually about one-half as wide (but, from slight curving of the branches, may for short distances be as wide) as the branches. Bifurcations not numerous.

Branches connected laterally both by slender, transverse dissepiments, and in places by transverse bands of epidermis; the latter about as wide as the branches. Judging from the few seen, the dissepiments are about 2.5 mm.

apart, but this may easily be erroneous, as intermediate ones may have been destroyed. The epidermis over the branches is in several places crossed by transverse lines which probably mark the position of thecae. These lines are approximately half a millimeter apart (corresponding to about 50 thecae in 25 mm.).

This species is easily recognizable by the rigid, wiry branches, very thickly set, with correspondingly narrow (nearly obliterated) meshes.



FIG. 47.—*Dictyonema parallelum*, new species. HOLOTYPE. (SEE ALSO PL. 4, FIG. 2.)

Horizon and locality.—Niagara dolomite, Hamilton, Ontario. Collector, Col. C. C. Grant.

Holotype.—Collection of Walker Museum, University of Chicago, No. 13505.

Genus CALYPTOGRAPTUS Spencer.

Calyptograptus SPENCER, Canadian Nat., VIII, 1878, p. 458.

Calyptograptus, LAPWORTH, Quart. Journ. Geol. Soc. London, XXXVII, 1881, p. 173.—SPENCER, Proc. Amer. Ass. Adv. Sci., XXXI, 1883, p. 364; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 562, 577; Bull. Mus. Univ. State Missouri, I, No. 1, 1884, p. 27.—MILLER, North Amer. Geol. and Pal., 1889, p. 175.—GURLEY, Journ. Geol., IV, 1896, pp. 93, 308.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 163.

Doctor Ruedemann^a publishes the following on this genus:

Spencer has erected the genus *Calyptograptus* for several species of the Niagara of Hamilton, Ontario, which are principally distinguished from the similar genera, notably *Dictyonema* and *Callograptus* by the absence of transverse dissepiments. In the first diagnosis it is stated that "in appearance and texture this genus resembles *Dictyonema*, but the branches are [apparently] all independent, not being connected by transverse dissepiments as in that genus and are only united in one mass at the root" [although some of the branches touching each other have occasionally all the appearance of connecting filaments]. This statement has later (1884) been qualified by the same author by the additions here placed in brackets, both of which tend to admit the occasional presence of dissepiments. The absence of the dissepiments and the independence of the branches down to the root, which may be considered as additional diagnostic characters of the genus, find their strictest expression in *C. cyathiformis* the form which is cited as the genotype by Miller [N. Am. Geol. and Pal. 1889, p. 175.]

CALYPTOGRAPTUS CYATHIFORMIS Spencer.

Calyptograptus cyathiformis SPENCER, Canadian Nat., VIII, 1878, pp. 458, 460; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 578, pl. 3, fig. 3; Bull. Mus. Univ. State Missouri, I, 1884, p. 28, pl. 3, fig. 3.—MILLER, North Amer. Geol. and Pal., 1889, p. 175, fig. 145.—GURLEY, Journ. Geol., 1896, pp. 93, 308.

The following is Doctor Spencer's original description, the bracketed portions being taken from his description published in 1884:

Frond cyathiform, with numerous bifurcating branches, united only at the base, with no lateral processes; the axis consists of a black corneous substance, which is striated longitudinally. The fallen frond has some of the branches overlying each other, forming a coarse [giving somewhat the appearance of an irregular] network. The radicle consists of a well-marked, thick, corneous mass.

The branches are about three-hundredths of an inch in breadth [rather over a millimeter]. The specimen under consideration is most interesting. When

^a New York State Mus., Memoir 11, 1908, p. 163.

obtained the frond had a general flabellate form with the radicle well marked, having branches radiating to nearly a semicircle; but on trimming the specimen the portion of the stem with radicle was chipped off and revealed the remainder of a beautiful frond which was now shown to be circular—the frond having been bent partly over in the mud, and having the lower portion covered before the whole was flattened in the sediment] thus proving the funnel-shaped character when living. This fossil is $2\frac{1}{4}$ inches in diameter, and from the base of the root to the top of the branches it measures 1 inch and a half.

It occurs in the Niagara limestone [beneath the chert at the "Jolly Cut"] at Hamilton, Ontario.

The description of 1884 also adds that the branches are divided into two or three small terminations which probably mark the beginning of new branches, and that only one specimen, 6 cm. in diameter, and 4 cm. from the base of the root to the top of the branches, was found. No additional specimens were noted in the more recent collections, so the species is undoubtedly very rare.

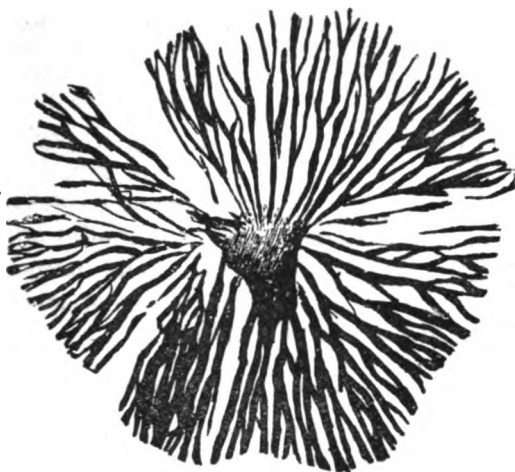


FIG. 48.—CALYPTOGRAPTUS CYATHIFORMIS SPENCER.
COPY OF SPENCER'S FIGURE.

CALYPTOGRAPTUS MICRONEMATODES Spencer.

Calyptograptus micronematodes SPENCER,
Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 579, 588, pl. 3, figs. 4, 4a; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 29, 38, pl. 3, figs. 4, 4a.

Calyptograptus micronematodes GURLEY,
Journ. Geol., IV, 1896, pp. 93, 308.

The original description is as follows:

Frond cyathiform in its growing state, with numerous lateral branches originating from the older stipes. The branches overlap each other, and may be united in some cases, but without true crossbars. The whole frond has an anastomose appearance with irregular rhomboidal

interstices. The texture is corneous (though sometimes replaced by pyrites, and the surface is marked with longitudinal striations, which in some places



FIG. 49.—CALYPTOGRAPTUS MICRONEMATODES SPENCER. COPY OF SPENCER'S FIGURE.

appear to represent the position of a solid central axis. The terminations of the branches end in two or three points. The branches in this species are very delicate being about a quarter of a millimeter broad, and each branch is not more than from 1 to 2 millimeters in length, before it overlaps or touches the adjacent stipe. The greatest diameter of the frond is not more than 4 cm. Only two or three specimens of this beautiful little frond have been obtained.



FIG. 50.—CALYPTOGRAPTUS MICRONEMATODES SPENCER. PLESIOTYPE IN SPENCER COLLECTION

Formation and locality.—I obtained this species near the base of the Niagara dolomite, at a quarry just west of the "Jolly-cut-road," Hamilton, Ontario.

A single specimen of this species, represented in figure 50, is at present extant in the Spencer collection. It does not permit of any substantial addition to the above description. The branches show some longitudinal chitinous striæ, but there are no indications of theæ or dissepiments.

CALYPTOGRAPTUS ? RADIATUS Spencer.

Calyptograptus ? radiatus SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 580, pl. 4, fig. 3; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 30, pl. 4, fig. 3.

Calyptograptus radiatus GURLEY, Journ. Geol., IV, 1896, pp. 93, 308.

The original description is as follows:

Frond ellipsoid, but cyathiform in its growing state. Numerous delicate branches, with two or three bifurcations, radiating from a common radicle. Some of these touch or overlap each other, but they are quite unconnected. The texture is corneous, with the surface striated and marked with minute depressions or pits, which indicate the former position of the cellule. These depressions are about the fourth of a millimeter in diameter, with an equal space between. The branches are about one-third of a millimeter broad. The greatest diameter of the frond is less than 3 cm. Fragments of this species so resemble species of *Callograptus* that they could not be readily distinguished; but in no species of the latter genus is the conspicuous funnel form apparent.

Formation and locality.—This fossil occurs in the "cherty beds" of the Niagara dolomite at Hamilton, Ontario.

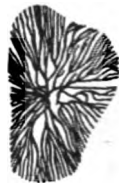


FIG. 51.—CALYPTOGRAPTUS ? RADIATUS SPENCER. COPY OF SPENCER'S FIGURE.

Subgenus RHIZOGRAPTUS Spencer.

Rhizograptus SPENCER, Canadian Nat., VIII, 1878, p. 460.—GURLEY, Journ. Geol., IV, 1896, pp. 101, 308.

Rhizograptus LAPWORTH, Quart. Journ. Geol. Soc. London, XXXVII, 1881, p. 176.—SPENCER, Proc. Amer. Ass. Adv. Sci., XXXI, 1883, p. 364; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 562, 580; Bull. Mus. Univ. State Missouri, I, 1884, p. 30.—MILLER, North Amer. Geol. and Pal., 1889, p. 202.

Below is given Doctor Spencer's original description, with additional characters, as published by him in 1884, placed in brackets.

Frond flabellate, but cyathiform in growing state; bifurcating branches with dichotomous terminations; [stem terminating in a well-marked bulb]; branches (marked with striæ) more or less reticulated, and united, or overlaid by others.

This genus is established on account of its *bulbous root*, which as yet has been found in no other species of this family. The numerous branches closely overlaid each other or are connected in the form of a network without transverse dissepiments, as in *Dictyonema*. Fragments of these somewhat resemble species of *Calyptograptus*, but have a much more [regularly] netted appearance and the branches are much more delicate.

Genotype.—*Rhizograptus bulbosus* Spencer.

RHIZOGRAPTUS BULBOSUS Spencer.

Rhizograptus bulbosus SPENCER, Canadian Nat., VIII, 1878, p. 460.—GURLEY, Journ. Geol., IV, 1896, pp. 101, 308.

Rhizograptus bulbosus SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, p. 580, pl. 4, fig. 4; Bull. Mus. Univ. State Missouri, I, 1884, p. 30, pl. 4, fig. 4.—MILLER, North Amer. Geol. and Pal., 1889, p. 202, text fig. 215.

The original description is as follows:

Frond cyathiform in growing state; numerous bifurcating branches overlaid each other, or are united at points of contact to form a network, with fine, more or less irregular, rhomboidal interstices. The branches unite at base into a slender axis which terminates in a bulbous root. The branches are usually less than one-fiftieth of an inch wide, and in some specimens short abrupt spinellike branchlets are given off. The texture is corneous. Only a few specimens have been obtained, except in fragments. Frond is about 2 inches high. It was first found by Colonel Grant in the Niagara limestones [near the base of the "chert bed" at the "Jolly-cut"; 1884] at Hamilton, Ontario.

Doctor Gurley's notes on this species are as follows:

The description of 1884 adds that the axis is athecaporous; that the striæ along the branches (which vary in thickness from 0.25 to 0.33 mm.) appear to mark the depressions of the common canal between the original positions of the polypites; that the thecal apertures have an ellipsoid form, and there are about 4 orifices in 1 mm.; and that on the side of the branch opposite the thecæ is a "solid axis."

After a careful examination of *Rhizograptus bulbosus*, in which the pseudo-meshwork is well preserved, I can find no criteria to justify its generic distinction from the *Calyptograptus* series, now that the basal "disk" has been found in the latter. While I would provisionally recognize *Rhizograptus* as a subgenus, I can not define it, and I think it probable that further study of large collections will lead to its entire suppression. The only difference I can see is a somewhat different aspect of the branches, which seem of a more rigid texture, more knotty and zigzag-flexuous than any of the *Calyptograptus* species.



FIG. 52.—RHIZOGRAPTUS BULBOSUS SPENCER. THE TYPE-SPECIMEN. (AFTER SPENCER.)

Genus ODONTOCAULIS Lapworth.

Odontocaulis LAPWORTH, Quart. Journ. Geol. Soc. London, XXXVII, 1881, p. 175.—POCTA, Syst. Sil. Centre Boheme, VIII, Pt. 1, 1894, p. 171.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 172.

Doctor Gurley remarks on *Odontocaulis* as follows:

This genus was thus established by Lapworth for forms which virtually combined two characters: (1) Absence of dissepiments, and (2) a polypiferous stem. Its only distinction from *Dictyonema* and *Callograptus* lay in these two features. But in *O. occidentalis* we find dissepiments along with the polypiferous stem. Whence there is now no generic distinction whatever between these two *Odontocaulis* species and the *Callograptus* species at the same horizon, except the single one of the thecae on the stem. But it is not at all improbable that this is merely a question of better preservation, well-preserved stems being thecate. At least, of the two specimens of *O. occidentalis*, both showing the stem, one shows thecae perfectly, the other only very obscurely.

Having said this, however, a contingency may properly be noted. May it be possible that all the *Callograpti* at this horizon have thecate stems (in other words, all be referable to *Odontocaulis*)? There is, I think, some ground for such a surmise. As Holm has said for *Dictyonema*, so now for *Callograptus*, the very great geologic range of the genus is a reason for suspecting the validity of the generic reference of the species. May it not then be possible that, compelled as we are for the most part to deal with and to base our species upon fragments of the meshwork, we are confounding two series; say, for illustration,^a a series lower Ordovician (Calciferous) in distribution, and a series upper Silurian (Niagara) in distribution, both series agreeing in type of meshwork (probably a character of subordinate biologic value), but differing in characters of the base. At present there is nothing to negative such a view. Until we know the proximal portion of the type species (*C. salteri*) this reasoning must, of course, remain purely a possibility. But in a review like the present a clear outlining of future possibilities may be justifiable. Certainly only under some such condition, it seems to me, would *Odontocaulis* stand much chance of ultimate retention. Its provisional retention I think advisable, pending a fuller knowledge of the condition of the base in the remaining Niagara *Callograptus* species. At present its most distinctive characters seem to be: Polypary arising from a single stem, which is expanded proximally into a "disk," and is thecaphorous along one side; distal branches more or less connected by dissepiments.

Genotype.—*Odontocaulis keepingi* Lapworth. Llandovery, of Devils Bridge, Aberystwyth, Cardiganshire.

ODONTOCAULIS GRANTI (Spencer).

Callograptus granti SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*: Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 571, 572, pl. 1, fig. 10; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 21, 22, pl. 1, fig. 10.—GURLEY, Journ. Geol., IV, 1896, pp. 93, 308.

The original description is as follows:

Frond originating from a single stipe; branches slender, and bifurcating two, three, or four times, and principally originating near the common radicle.

^a For illustration only, and as a pure surmise of the possibilities of the case.—R. R. Gurley.

In spreading gently above in undulations the branches are more or less parallel and situated closely together, and are connected occasionally with exceeding fine transverse bars. The texture is corneous, with the surface obliquely striated and marked with ellipsoid pits, which in some places indicate the orifices of the cells, of which there were about two for every millimeter of length of branch. The branches are rarely connected by minute crossbars.

The general outline is that of a regular oval form, whose length, in the most perfect specimens, is 3 cm. (besides the common stipe, which extends another centimeter), and breadth, 2 cm. The branches are not more than a quarter of a millimeter broad, while the stipe is about double that thickness.

This exceedingly beautiful frond in general appearance closely resembles *C. salteri* of the Quebec group but somewhat smaller, though there is some variation in the size of this species.

Formation and locality.—This species occurs on the shaly surfaces of the Niagara dolomites at Hamilton, Ontario.

Gurley's notes are as follows:

Of this species five specimens, certainly conspecific, were seen. The one figured in text figure 54 differs slightly from Spencer's figure in having the branches somewhat more closely arranged, but in spite of this the identification seems to me almost certain. This specimen has about 50–55 branches in 25 mm. of width. The branches are about 0.25 mm. wide. The dissepiments would seem to have been somewhat numerous; being very delicate, however, most of them are covered or destroyed.

One specimen in the Spencer collection shows the basal stem and the proximal portion of the polypary. Dissepiments are present. The basal stem bears two distinct thecae at its summit and obscure indications of them below. It is somewhat expanded at its lower end, appearing as though beginning to expand into a "disk."

C. granti then belongs to the *Odontocaulis* section, whatever may ultimately prove to be the taxonomic rank of that section.

Horizon and locality.—Five specimens: One in Spencer collection, one in New York state collection, and three in U. S. National Museum collection; all five from the Niagara formation, Hamilton, Ontario.

Plesiotype.—Cat. No. 55305, U.S.N.M.

ODONTOCAULIS OBPYRIFORMIS Gurley, new species.

This new species is based on a single specimen in the Spencer collection, and is described by Gurley as follows:

Polypary pyriform, broad end distal, 22 mm. long by 15 mm. broad, arising from a thecate stem extending about 25 mm. below the meshwork and there broken off; bearing three thecae, introverted somewhat as in the *Dicranograptidae*. Reticular portion of the polypary,



FIG. 53.—*ODONTOCAULIS GRANTI* (SPENCER). A RHABDOSOME AND A BRANCH OF SAME ENLARGED. (AFTER SPENCER.)



FIG. 54.—*ODONTOCAULIS GRANTI* (SPENCER). AN INCOMPLETE RHABDOSOME.



FIG. 55.—*ODONTOCAULIS OBPYRIFORMIS*, NEW SPECIES. VIEW OF THE HOLOTYPE SHOWING RHABDOSOME AND STEM ENLARGED.

arising at summit of stems by dichotomy, the branches likewise dichotomizing, the total number of divisions, including the primary, being five or six. In form they are U-shaped. Branches 0.3 mm. wide throughout, except at the extreme base where 4.0 mm. is reached. Peduncle 0.6 mm. wide. Branches set in the proportion of 27 in 25 mm. Dissepiments fairly numerous, being, in some places, as close together as 1 mm.

Horizon and locality.—One specimen from the Niagaran chert, Hamilton, Ontario.

ODONTOCAULIS OCCIDENTALIS Gurley, new species.

Gurley's description and remarks upon this new species are as follows:

Polypary pedunculate-cyathiform showing in both specimens an under layer separated by a "cliff" of rock from and exactly corresponding to the upper layer, as in *Dictyonema*, originating in a stem plainly thecaporous, but not preserved as far down as the disk, with a virgula (?)^a 0.2 mm. wide. Stem 0.8 mm. wide to the apices of the thecæ; 0.6 mm. to the bottom of the depressions. Greatest height seen 38 mm., of which the stem takes up 11. Thecæ 40 in 25 mm. Polypary spreading at once unilaterally, almost rectangularly, from the summit of the stem and a little higher up for about 30° to the other side. Branches 0.4 mm. in diameter, flexuous, set rather distantly and quite variably, but mostly about 25 in 25 mm. Dissepiments present, but few and remote. Thecæ visible in few places on branches.



FIG. 56.—ODONTOCAULIS OCCIDENTALIS, NEW SPECIES. A RATHER COMPLETE RHABDOSOME.

Besides the above characters, the figured specimen shows the basal disk, the initial dichotomous division at the summit of the stem, dissepiments, and the cyathiform character of the polypary, the lower layer being visible underlying a "cliff" of rock. On the stem I think I can trace thecæ, but they are too obscure to speak certainly.

Horizon and locality.—Niagara chert, Hamilton, Ontario.

Cotypes.—Cat. No. 55306, U.S.N.M.; Walker Museum, University of Chicago, No. 13514.

Genus CYCLOGRAPTUS Spencer.

Cyclograptus SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*: Proc. Amer. Assoc. Adv. Sci., XXXI, 1883, p. 365; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 563, 592; Bull. Mus. Univ. State Missouri, I, 1884, p. 42.—MILLER, North Amer. Geol. and Pal., 1889, p. 182.—GURLEY, Journ. Geol., IV, 1896, pp. 94, 309.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 182.

^a It certainly bears some appearance of being a true virgula. Were the stem alone and the rock stated to be Lower Silurian, no one would hesitate to pronounce it a virgula. But as this is the only case in these Upper Silurian Dendroidea where I have seen any close resemblance to a virgula, doubt is but natural.—R. R. Gurley.

Spencer's description of this genus is as follows:

In this genus, the frond consists of a circular disk which was probably cup-shaped in its growing form, though flattened in a concave manner in the rock. From the radicle many stipes radiate through the noncelluliferous disk to its margin, and thence in a free manner to some distance beyond. The whole frond resembles a solid wheel, where the radiating spokes extend from the center regularly to beyond the circumference. The branches beyond the disk are celluliferous. The stipes have a central solid axis. The substance is highly corneous, though in some places replaced by pyrites.

Doctor Ruedemann has reviewed this genus in his monograph, to which the reader is referred for comparisons between this and related genera.

Genotype.—*Cyclograptus rotadentatus* Spencer.

CYCLOGRAPTUS ROTADENTATUS Spencer.

Cyclograptus rotadentatus SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 565, 592, 593, pl. 6, figs. 6, 6a; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 42, 43, pl. 6, figs. 6, 6a.—MILLER, North Amer. Geol. and Pal., 1889, p. 182, text fig. 162.—GURLEY, Journ. Geol., IV, 1896, pp. 94, 309.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 184, pl. 2, fig. 5.

Doctor Spencer's original description is given below:

Frond circular, with numerous stipes radiating from a common center and projecting like a toothed wheel beyond the margin of a noncelluliferous disk.



FIG. 58. — CYCLOGRAPTUS ROTADENTATUS SPENCER. A LARGE SPECIMEN FROM THE CLINTON GROUP, CLINTON, N. Y. (AFTER RUEDEMANN).

The frond was probably cup-shaped when growing, with the stipes projecting upward like a row of spines or tentacles, but in the rock the fossil is flattened and slightly convex.

The stipes originate in the center and are connected about half their length by their continuous noncelluliferous membrane. Each stipes after passing beyond their solid disk divide into two branches about halfway between their extremities and the margin of the disk. The branches or stipes are traversed by a central cylindrical, smooth, solid axis surrounded by their common canal, which is sometimes only represented by a central depression or elevation, but occasionally its form is well

preserved. The rarely indicated cell openings are represented by minute oval depressions in the substance. The texture is highly corneous (or replaced by pyrites).

The diameter of the frond is 2 cm., and of the disk 1 cm.; the radiating branches extend half a centimeter beyond the disk, and number between 25 and 30, but, as each is divided, the frond is surrounded by about 60 points. The branches (both through the disk and free portion) are rather over half a millimeter broad, but the terminals are scarcely more than half that thickness and end in sharp points.



FIG. 57. — CYCLOGRAPTUS ROTADENTATUS SPENCER. COPY OF SPENCER'S FIGURE.

Formation and locality.—This perfect little species was found in the dolomite of the Niagara formation proper, near the base of the series, at the quarry just west of the "Jolly-cut" road at Hamilton, Ontario.

Doctor Ruedemann has recently figured a specimen referred to this species, found in the upper part of the Clinton, at Clinton, N. Y. (See text, fig. 58.) Except in the matter of size, this example does not differ from the original type.

Genus INOCAULIS Hall.

Inocaulis HALL, Amer. Journ. Sci. (2), XI, 1851, p. 401; Nat. Hist. New York, Pal., II, 1852, p. 176; 20th Rep. New York State Cab. Hist., 1868, p. 218 (rev. ed., 1868 [1870], p. 252).—NICHOLSON, Mon. Brit. Graptolitidæ, 1872, p. 131.—SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 562, 583; Bull. Mus. Univ. State Missouri, I, 1884, p. 33.—MILLER, North Amer. Geol. and Pal., 1889, p. 193.—JAMES, Journ. Cincinnati Soc. Nat. Hist., XIV, Pt. 2, 1892, p. 161.—POCTA, Syst. Sil. Centre Bohême, VIII, Pt. 1, 1894, p. 197.—ELLES and WOOD, Mon. Brit. Graptolites, Pal. Soc., 1903, p. xxxiv.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 185.

Hall's original description of this genus is as follows:

A plantlike, corneous coral, with numerous bifurcating branches; structure fibrous or plumose.

The texture of this coral is similar to the Graptolites, a black scaly crust or film being all that remains of the substance. From the specimens examined, it appears to have grown in groups, with rounded or flattened stems, which are dichotomous above and more or less spreading. The structure is too peculiar to be mistaken or to be referred to any established genus.

Genotype.—*Inocaulis plumulosus* Hall. Niagaran of New York and Canada.

The characters of both the genus and its type species have been discussed by Doctor Ruedemann in his monograph.

INOCAULIS PLUMULOSUS Hall.

"———" ? HALL, Rep. Surv. 4th Geol. Dist. New York, 1843, p. 116, fig. 1.

Inocaulis plumulosa HALL, Nat. Hist. New York, Pal. II, 1852, p. 176, pl. 40G, figs. 2a, 2b; Geol. Surv. Canada, Can. Org. Rem., Decade 2, 1865, p. 18, fig. 26; 20th Rep. New York State Cab. Hist., 1868, p. 185, text fig. 28 (rev. ed., 1868 [1870], p. 215, text fig. 28).—NICHOLSON, Mon. Brit. Graptolitidæ, 1872, p. 132, text fig. 73.

Inocaulis plumulosus SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, p. 534, pl. 5, fig. 1; Bull. Mus. Univ. State Missouri, I, 1884, p. 34, pl. 5, fig. 1.—MILLER, North Amer. Geol. and Pal., 1889, p. 193, text fig. 183.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 188, pl. 2, fig. 4; pl. 7, figs. 1, 2.

Doctor Gurley's manuscript contains an elaborate description of this species, but the description and remarks published by Doctor Ruedemann are more to the point and are reproduced below :

Hall has given the following diagnosis of this species :

Stems flattened, dichotomous; structure fibrous or plumulose, apparently composed of imbricating elongated scales or fibers which spread equally on all sides.

This coral is not abundant, though small fragments are frequently seen in the slab. It is very often replaced by iron pyrites, and where the surface



FIG. 59.—*INOCAULIS PLUMULOSUS* HALL. A RATHER COMPLETE RHABDOSOME.

is exposed to weathering, the fossil soon disappears so that it is only on freshly fractured surfaces that the structure is preserved.

It is cited as occurring in the "Niagara shale at Lockport, Rochester, and other places."

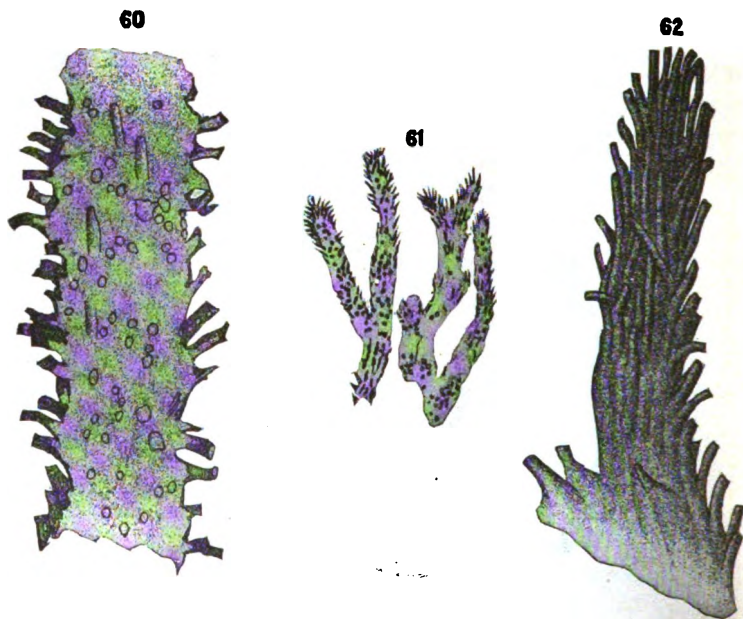
Spencer has recorded the form from the Niagara limestone at Hamilton, Ontario.

Gurley, in his manuscript, adds to the descriptions of Hall and Spencer in the following note:

Two specimens from the Niagara formation, at Hamilton, Ontario, are figured, showing the blunt toothlike bodies and the apparently dentate margin. While the appearance much resembles thecae, it is impossible to make a positive statement on the material available.

From a fairly large series of good specimens we derive the following data on this important species:

The rhabdosome is arborescent in form; the branches divide dichotomously at irregular intervals, forming initial angles of 50° – 60° but becoming later subparallel; of large dimensions (maximal length of largest fragment observed 14 cm., width of another 17 cm.), the stem near base 5 mm. thick, the branches quite uniformly 3 mm. The branches diminish hardly toward the distal ex-



FIGS. 60–62.—*INOCAULIS PLUMULOSUS* HALL. 60, PORTION OF A BRANCH, $\times 5$; 61, DISTAL PORTION OF BRANCHES SHOWING TUBULAR BRANCHLETS AND IMPRESSIONS OF THEIR APERTURES; 62, TERMINAL PORTION OF A BRANCH.

tremities which are bluntly rounded. The stem is apparently smooth, the branches are thickly set with short tubular processes which project about 1 mm. from the body of the branch, are of uniform width, directed upward and distally slightly bent backward and number, counted along the margin, about 14 in 10 mm. On specimens where the body of the branch has weathered away, exposing the apertures of the reverse side, they are seen to be distributed about equally over the whole branch, being approximately arranged in quincunx and numbering about five in the width of the stem. At the extremities of the branch they form dense tufts.

Remarks.—The general habitus of *I. plumulosa* can be best described by a comparison with a *Lepidodendron* or a *Lycopodium*; it not only resembles these plants in the mode of its branching and the uniformly wide, blunt ending branches, but also in their scaly appearance.

Hall's original and later improved figures give a good conception of the general appearance of the form. A more complete specimen from the Lockport

limestone at Hamilton is here reproduced in text figure 93 [59] by a pen drawing made under Gurley's supervision. In Plate II, figure 4 [text fig. 61] a portion of the same specimen which is partly weathered has been refigured to show the thecae. Where in unweathered specimens the perisark is partly broken away [as in text fig. 60], the circular sections of the composing tubes can be seen and the whole branch is found to be composed of apparently equal tubes.

The rhabdosome, when more complete than in the specimens hitherto mentioned, forms a dense mass of overlapping branches, which on account of the frequent dichotomies and later reapproachments of the branches assumes to some extent the aspect of a huge *Desmograptus*.

We have been unable to see in any of our or Spencer's rhabdosomes the central axis which he asserts to have observed in a number of specimens, and we doubt, from the general structure of this form, that such a thing as a central axis existed.

Horizon and locality.—The type is from the Niagara shale of New York, and the specimen here figured (text fig. 59) from the same horizon at Hamilton, Ontario.

Plesiotype.—Cat. No. 54281, U.S.N.M.

INOCAULIS RAMULOSUS Spencer.

Inocaulis ramulosa SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*.

Inocaulis ramulosus SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 585, 588, 589, pl. 6, fig. 1; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 38, 39, pl. 6, fig. 1.—GURLEY, Journ. Geol., IV, 1896, pp. 99, 309.

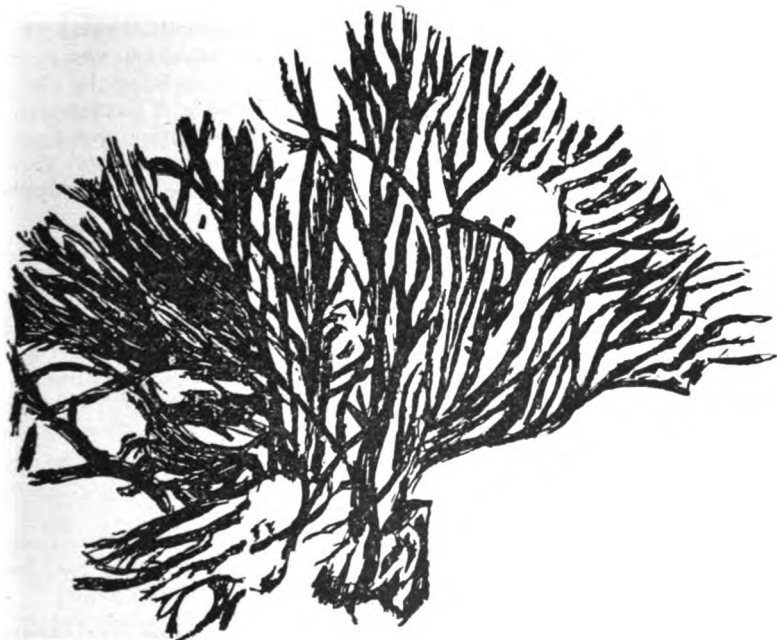


FIG. 63.—INOCAULIS RAMULOSUS SPENCER. COPY OF SPENCER'S FIGURE.

The original description by Spencer is as follows:

Frond consisting of numerous flattened bifurcating branches, originating in and radiating from a common radicle, composed of solid chitinous matter;

branches averaging 2 mm. in breadth for the larger and 1 mm. for the smaller; toward the margin of the frond, where the branchlets end in two (sometimes three) extensions of unequal thickness. Texture corneous, with the surface composed of scaly fibers. Extending longitudinally through the stipes are central or subcentral elevations (sometimes depressions), indicating a solid central axis.

This species is described on two specimens, one of which shows the origin and base of the radiating branches, and the other the general frond, although the radicle is concealed. The extreme width of the typical specimen is 14 cm., and the height 8 cm.



FIG. 64.—*INOCAULIS RAMULOSUS* SPENCER. SPECIMEN
IN U. S. NATIONAL MUSEUM.

In general form this species differs from *I. plumulosus* in that the branches are more slender and rise regularly and more abundantly from the sides of the main stipes, which radiate from a common origin and do not consist of groups of individual fronds. The radicle appears to have been attached to some rocky surface in the sea, and not to have grown on some muddy bottom. The cell-bearing stipes appear to have had a common canal, through the center of which was a central solid axis, as is also indicated in *I. cervicornis*.

Formation and locality.—

These specimens were obtained in the shaly dolomites, below the "chert beds" of the Niagara formation at the "Jolly-cut," Hamilton, Ontario.

Doctor Gurley's notes are as follows:

Polypary, in the single specimen seen, rising from a stem which gives off, in the proximal half of the portion visible, very few branches which, moreover, do not rebranch into a bushlike form, the bushlike branching occurring only in the distal half of the polypary. The only proximal branch distinctly seen bears a close spike of straplike processes (abortive branchlets?). Distally the polypary branches out bushlike, the main branches about 1 mm. thick. At or near the summit the branches subdivide into 2 or 3, usually unequal or subequal, terminal twiglets. The sides of the branches are usually slightly fringed; the processes hairlike, few and remote.

The stems of this species remotely resemble those of *Acanthograptus granti*, but they are much more remotely and much more finely fringed, and in its ensemble this species has the branches less rigid and parallel than has *A. granti*.

Horizon and locality.—Niagaran (Lockport), Hamilton, Ontario.

Plesiotype.—Cat. No. 55314, U.S.N.M.

INOCAULIS CERVICORNIS Spencer.

Inocaulis cervicornis SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 565, 587, pl. 5, fig. 5; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 37, pl. 5.—GURLEY, Journ. Geol., IV, 1896, pp. 99, 308.

The original description is as follows:

Frond consisting of stipes having a common origin and rising above into a few stout, widely extended, bifurcating branches, averaging from 1.5 to 2 mm. in breadth, and terminating in dichotomous points of equal thickness; texture corneous, with a striated surface.

Owing to the striations the appearance of the surface is that of rough scales or fibers, somewhat resembling the exterior portion of *I. plumulosus*. In the growing state the branches appear to have been strengthened by longitudinal fibers—solid corrugations—and the cells to have been arranged vertically between them. A portion of the branches show a solid central axis, with a common canal surrounding it. The general arrangement of the branches resembles that of the horns of the American elk.

The typical specimen consists of 6 principal stipes, each about 3 centimeters long, with only a few branches. These stipes are united by a common runner (in the botanical sense), so that the whole organism is 5 centimeters broad and 3 centimeters high.

Formation and locality.—This rare and beautiful species occurs in the shaly dolomites of the Blue Building beds of the Niagara formation at the "Jolly-cut," Hamilton, Ontario.

A single specimen in the collection of the U. S. National Museum is known, but presents no additional information.

INOCAULIS PHYCOIDES Spencer.

Inocaulis phycoides SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*.

Inocaulis phycoides SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 565, 588, pl. 5, figs. 6, 7; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 38, pl. 5, figs. 6, 7.—GURLEY, Journ. Geol., IV, 1896, pp. 99, 309.

The original description is as follows:

Stem flattened and from 2 to 3 mm. broad; branches fastigiate, and originating on both sides of the principal stipe at frequent irregular intervals, and dividing near their terminations into two stout branchlets (from $\frac{3}{4}$ to $1\frac{1}{2}$ cm.



FIG. 65.—*INOCAULIS CERVICORNIS* SPENCER.
COPY OF SPENCER'S FIGURE.

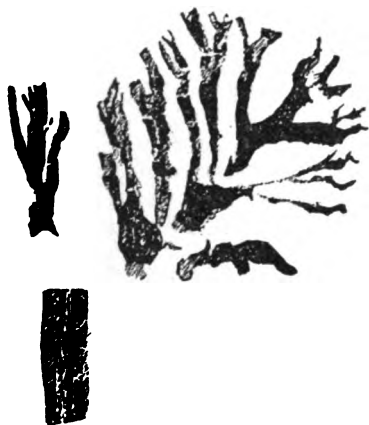


FIG. 66.—*INOCAULIS PHYCOIDES* SPENCER.
THE TYPE-SPECIMEN AND A BRANCH ENLARGED.

long), each ending in dichotomous free points. Texture corneous, with a surface apparently composed of scaly fibers.

Of this species the fossils are not very well preserved. There is some indication of a central axis. This species is easily distinguished from *I. plumulosus* by the close, regularly arranged, parallel branches from each side of the principal stipes and by their terminal branches. The fronds appear to have grown in groups, but whether they are connected at the base or not is unknown. If not connected, the individual fronds (in the specimens under consideration) are about 4 cm. high and 3 broad, with from 3 to 5 principal branches on either side of the central stipe (the branches are more numerous on one side than the other). The character of the cellules is unknown.

Formation and locality.—*Inocaulis phycoides* occurs in the dolomitic limestones of the Niagara formation at the "Jolly-cut" quarries, Hamilton, Ontario.

A specimen doubtfully referred to this species occurs in the National Museum collections, but shows nothing in addition to the above.

INOCAULIS DIFFUSUS Spencer.

Inocaulis diffusa SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*.

Inocaulis diffusus SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 565, 586, 587, pl. 5, fig. 4; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 36, 37, pl. 5, fig. 4.—GURLEY, Journ. Geol., IV, 1896, pp. 90, 308.

This species was described by Spencer as follows:

Frond originating in a single stipe at base, and rising above in numerous widely extended branches averaging about a millimeter in breadth, with dichotomous terminations; branchlets originating more frequently on one side than on the other. Texture corneous,



FIG. 67.—*INOCAULIS DIFFUSUS* SPENCER.
COPY OF SPENCER'S FIGURE.

with surface more or less regularly striated, leaving in some places small oval impressions (probably the orifices of the cellules).

Of this species I have seen only one good specimen (and two inferior fragments which probably belong here). The frond is 6 cm. high and of still greater breadth. One of the branchlets of the dichotomous termination is much more slender than the other (a sort of lateral pustule), indicating probably the commencement of the growth of a new branch.

The general form of this species is like *I. bellus* (Hall and Whitfield), but it is much larger in size, having more diffused branches, with an entire absence of prong-like processes from its sides.

Formation and locality.—The type of this species was obtained by Colonel Grant, near the base of the "cherty bed" at the "Jolly-cut," Hamilton, Ontario, in the Niagara dolomite.

Doctor Gurley has the following notes based upon a specimen (text fig. 68) referred to this species by him:

The (fragmentary) polypary consists of a main stem the sides of which are beset with spinular processes similar to those found in *Inocaulis*. The branching is at an acute angle (about 35°). The main stem is about 0.8 mm. wide. The spinular processes are 0.5–0.6 mm. apart (too few are visible to state the number in 25 mm.). Besides these processes two others of a different character, 1 mm. long, are visible. They belong to the class regarded by Spencer as rudimentary branchlets. Both stem and branches are longitudinally striate, many distinct chitinous fibers being visible.

Horizon and locality.—Niagara limestone and chert, Hamilton, Ontario.

Plesiotype.—Cat. No. 55315, U.S.N.M.



FIG. 68.—*INOCAULIS DIFFUSUS* SPENCER. SPECIMEN DESCRIBED BY GURLEY.

INOCAULIS DIFFUSUS CRASSIRAMUS Gurley, new variety.

Plate 5, figure 2.

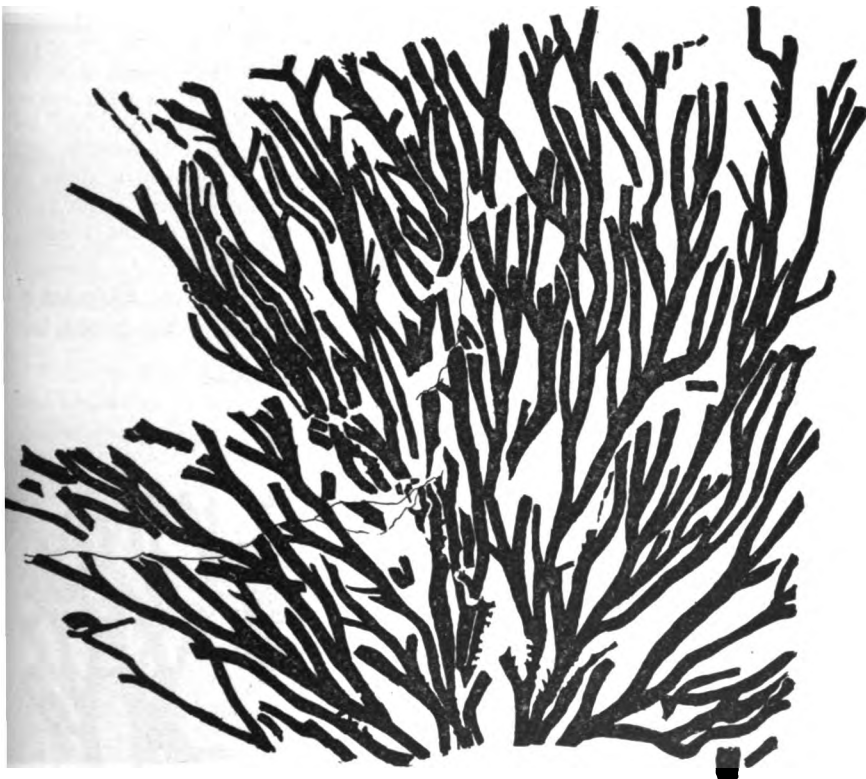


FIG. 69.—*INOCAULIS DIFFUSUS CRASSIRAMUS*, NEW VARIETY. HOLOTYPE.

One specimen, which, judging from Spencer's figure and description, seems to have the habit of *I. diffusus*, is described by Gurley as a variety as follows:

Polypary consisting of numerous branches not widely radiating, 2 mm. wide *ad max.*; the smallest seen about 1 mm. wide; longitudinally striated by very

fine fibers; showing on the margins some blunt triangular processes, about 0.5 mm. wide and projecting about 0.5 mm. from the stem and about 1 mm. apart. From the present material it would seem as though these processes form a somewhat less prominent feature than in *I. diffusus* and in *I. scalkeri*, but this is somewhat doubtful.

The principal difference between this variety and *I. diffusus* proper is the considerably greater thickness of the branches and the lesser prominence of the lateral blunt spines. The latter feature, however, may be a condition of preservation, and the former distinction may possibly be obliterated by a larger series of specimens.

Horizon and locality.—Niagara dolomite (blue building bed), Hamilton, Ontario.

Holotype.—Walker Museum, University of Chicago, No. 13507.



FIG. 70.—*INOCAULIS CONGREGATUS*, NEW SPECIES. HOLOTYPE.

INOCAULIS CONGREGATUS Gurley, new species.

A single specimen in the collection of the Walker Museum is the basis of this species, described by Gurley as follows:

Polypary consisting of a number (about 8 in the type-specimen) of approximated and parallel stems, which are set 20 in 25 mm. transversely, and are simple for about 25 mm. Several bifurcate at this level; the central ones, however, bifurcate about 10 mm. higher up. Thickness of main stem about 1–1.2 mm.; of branches nearly the same (about 1 mm.).

Thæcæ obscure, the margins of the branches obscurely subserate.

Horizon and locality.—Niagaran formation, Hamilton, Ontario.

Holotype.—Walker Museum, University of Chicago, No. 13508.

INOCAULIS ? STRICTUS Gurley, new species.

Plate 2, figure 6.

The description by Gurley is as follows:

Branches rigid, not spreading, but upright and rather straight, bifurcating at a comparatively small angle (about 45°), diminishing in width from 2 mm. at the proximal end of the fragment to 1.5 (rarely to 1) mm. at the distal. Margins generally smooth, in one or two places subserate. Successive bifurcations rather frequent (distant 5 to 10 mm.).



FIG. 71.—*INOCAULIS ? STRICTUS*, NEW SPECIES. HOLOTYPE. (SEE ALSO PL. 2, FIG. 6.)

Horizon and locality.—Niagara chert, Hamilton, Ontario; one specimen (the type) in the Spencer collection, one specimen in Grant collection.

INOCAULIS VEGETABILIS Gurley, new species.

Plate 5, figure 1.

Gurley describes this species as follows:

A specimen in the New York State collection has the mode of growth characterizing *I. phycoides*, but is *very* much stouter in every way, the thickness of the stem and main branches reaching 6 or even 7 mm. and the terminal branches measuring 3 and 4 mm. Still it is not absolutely impossible that the difference may be merely one of age or distance from the point of origin of the polypary, but there is at present nothing to show that this is the case.

The substance is in this case preserved in places, and forms a thick, coal-black film with longitudinal striations and furrowing corresponding to fibers and bands. No thecae are visible.

Horizon and locality.—Niagaran (Lockport), Hamilton, Ontario.

Holotype.—New York State collection.

INOCAULIS ? THALLOSUS Gurley, new species.

Plate 2, figure 5.

Gurley describes this species as follows:

Polypary 15 mm. long and 9 mm. in extreme breadth, consisting of a main stem about 1 mm. thick, from which proceed laterally at a little less than a right angle, branches about 0.6 mm. wide and about 5 mm. or less long. The branches bifurcate about 1.5 mm. from the stem, and farther on redivide.

Only a single specimen (obverse and reverse) of this species was seen. The species simply show as a stain (but a well-outlined stain) on the rock, with little or no evidence of graptolite structure. It is therefore possible that this species does not belong to the graptolites, but at any rate it seems to be new and is a part of the fauna.

Horizon and locality.—Niagara limestone at base of chert, Hamilton, Ontario.

Holotype.—Cat. No. 55316, U.S.N.M. The reverse is in the Spencer collection.

Genus ACANTHOGRAPTUS Spencer.

Acanthograpsus SPENCER, Canadian Nat., VIII, 1878, p. 461.

Acanthograptus LAPWORTH, Quart. Journ. Geol. Soc. London, XXXVII, 1881, p. 174.—SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 562, 581; Bull. Mus. Univ. State Missouri, I, 1884, p. 31.—MILLER, North Amer. Geol. and Pal., 1889, p. 170.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 191.

The original description is as follows:

Frond shrublike, consisting of thick branches, principally rising from near the base, with little divergence and some bifurcations. One side of the branches is furnished with prominent spines or dentacles, which appear to mark the cell-apertures. Texture corneous and indistinctly striated. This

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generic form resembles *Dendrograpsus*, but it is stronger and more bushy than species of that genus, and has conspicuous spines indicating a different cell structure [in whose axils the thecae were probably situated; 1884].

Gurley adds in his manuscript to Spencer's definition of the genus:

This is apparently a good genus, including several species which present a very similar facies, principally in the plumulose branches with a tendency to a 2- or 3-spicate termination. But if this genus be altogether distinct from *Inocaulis* (a point on which at present I do not feel positive), it is certainly here that Spencer's *Inocaulis walkeri* belongs.

Genotype.—*Acanthograptus granti* Spencer. Niagaran (Lockport), Hamilton, Ontario.

ACANTHOGRAPTUS GRANTI Spencer.

Plate 2, figure 1; Plate 3, figure 4.

Acanthograptus granti SPENCER, Canadian Nat., VIII, 1878, pp. 458, 461, 462.
Acanthograptus granti SPENCER, Canadian Nat., X, 1882, p. 165; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 504, 582, pl. 4, fig. 5; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 32, pl. 4, fig. 5.—GURLEY, Journ. Geol., IV, 1896, pp. 92, 308.

The original description is as follows:



FIG. 72.—ACANTHOGRAPTUS GRANTI SPENCER. COPY OF SPENCER'S FIGURE.

Frond shrublike, with thick branches principally originating near the base. Some of the branches are bifurcated and have the ends dichotomous; cell apertures on one side only, and indicated by prominent spines which appear to be placed below them. The branches are sometimes the sixteenth of an inch broad, with spines in some places projecting the twenty-fourth of an inch and ending abruptly.

The larger fronds do not exceed two inches in height and sometimes have the same width.

This species was first obtained [in the Niagaran dolomites; 1884] at Hamilton, Ontario, by Colonel Grant.

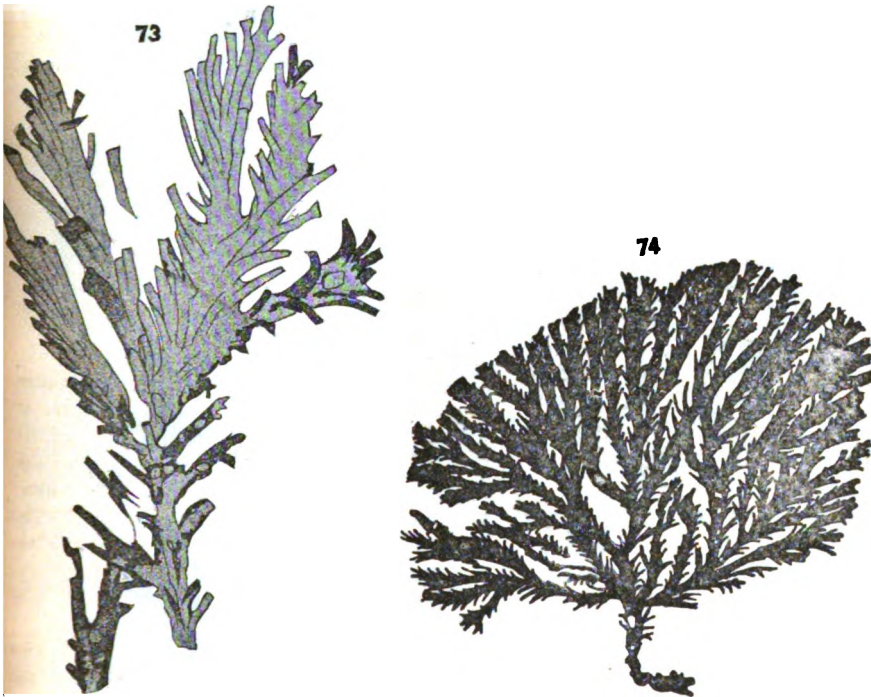
The description of 1884 adds the following data:

Surface longitudinally striated. Occasionally there are rudimentary denticles appearing also on the opposite side of the branch as well as on that marked with the regular spinelike projections, of which there are 6 or 7 in the length of a centimeter of the stipe, which is characterized by obscure indications of a solid central axis. The branches average a millimeter in breadth, and the spines are sometimes a millimeter long, which in some places extend into the material of the stipe to its center. The flattened frond is usually 4 or 5 cm. high and about 4 wide, and consist of 15 or 20 branches at half its height, which are somewhat more numerous at the summit, owing to occasional bifurcations. The whole frond originates from a common radicle.

The best preserved graptolites that are found at Hamilton occur on the shaly surface of the limestone, but this species is only found in the highly crystalline rock, and consequently, although the general form of frond is well preserved and very beautiful, the detailed structure is not shown as well as in the forms that are found in the more perishable shaly rocks.

Gurley adds the following:

This species is easily recognizable among the now known *Acanthograptus* species by the very heavy branches, which very generally measure 1 mm. or a little more, though occasionally one as narrow as 0.8 mm. is seen. As regards



FIGS. 73, 74.—*ACANTHOGRAPTUS GRANTI* SPENCER. 73, DISTAL PORTION OF RHABDOSOME, $\times 5$; 74, A NEARLY PERFECT RHABDOSOME. (AFTER RUEDEMANN.)

number, they are set rather irregularly, but usually there are about 15 in 25 mm. of width. The specimens show no evidence of thecae or of a virgula.

Plesiotypes.—Cat. No. 55310, U.S.N.M. Specimen figured on Plate 2, figure 1, in Spencer collection.

***ACANTHOGRAPTUS WALKERI* (Spencer).**

Inocaulis walkeri SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 585, 586, pl. 5, fig. 2; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 35, 36, pl. 5, fig. 2.—GURLEY, Journ. Geol., IV, 1896, pp. 99, 309.

Acanthograptus walkeri RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 194, pl. 6, figs. 1, 2; pl. 7, fig. 4, text figs., 97, 98.

Spencer's diagnosis reads:

Frond strong, with spreading branches, the margin having a plumulose appearance; structure corneous, with a central axis, and the surface covered with minute points representing the cell-apertures.

This frond somewhat resembles *I. plumulosus*, but it is slighter, and the branches (not exceeding 1.5 mm. in thickness) are much more numerous and proceed from a single stipe. The type specimen has a height of 8 and a breadth of 6 cm.

Formation and locality.—This species occurs in the Niagara limestones at Hamilton, Ontario.

Doctor Gurley describes the species as follows:

Polypary of general dendroid aspect; main branches mostly 1-1.5 mm. thick, a width of 2 mm. being only seen once, immediately below a bifurcation. Branching not very regular. Usually at the proximal end several branches



FIG. 75.—*ACANTHOGRAPTUS WALKERI* (SPENCER).
COPY OF SPENCER'S FIGURE.



FIGS. 76, 77.—*ACANTHOGRAPTUS WALKERI* (SPENCER).
TWO FRAGMENTARY SPECIMENS.

are somewhat clustered, and diverge thence radiatingly. On one specimen which I hardly feel able to separate, the branching is rather more from a main axis. The branches, especially the main ones, are thickly beset (spinose shaggy) with the long, blunt, obliquely upward-directed denticles, which are about 25 in the space of 25 mm. They differ much in appearance in different parts of the polypary, if, indeed, there are not more than one kind of them. Sometimes on the main stem they are blunter (about 1.0 mm. long and 0.1 mm. wide at base), while on the branches and branchlets they are less blunt. But on the main stem and principal branches longer, narrower, and less regular and more hairy root-like processes occur.

This species can be told by the distinct and numerous "denticles" on both sides of stem and branches, finer and less blunt dentate than in *A. granti*.

Horizon and locality.—Niagaran (Lockport), Hamilton, Ontario.

Plesiotypes.—Cat. Nos. 54277, 55317, U.S.N.M.



FIGS. 78-80.—*ACANTHOGRAPTUS WALKERI* (SPENCER). 78, BRANCHES SHOWING BRANCHLETS AND THECAL APERTURE, $\times 5$; 79, A SPECIMEN NATURAL SIZE, ROCHESTER SHALE, NEW YORK; 80, FRAGMENT OF BRANCH, $\times 5$, ROCHESTER SHALE, NEW YORK. (79 AND 80 ARE AFTER RUEDEMANN.)

ACANTHOGRAPTUS PULCHER Spencer.

Plate 4, figure 5.

Acanthograptus pulcher SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 564, 582, 583, pl. 4, fig. 6; Bull. Mus. Univ. State Missouri, I, 1884, pp. 14, 32, 33, pl. 4, fig. 6.—MILLER, North Amer. Geol. and Pal., 1889, p. 170, fig. 128.—GURLEY, Journ. Geol., IV, 1896, pp. 92, 308.

The original description is as follows:

This frond is broadly flabellate, but was possibly cyathiform in its growing state. Very numerous branches (with few principal subdivisions) arise from a common radicle and extend in an entirely free manner to the even and more or less circular margin of the frond. Along both sides of the branches many short rudimentary branchlets arise. Besides these, there are numerous spine-like processes, which possibly indicate the position of the cellules. The texture is corneous, with the surface striated, and in some places, where removed, there are indications of a lateral solid axis. From the center of the radicle the branches extend a distance of about $2\frac{1}{2}$ mm. [centimeters. R. R. G.] to the margin of the ground [frond. R. R. G.], or the diameter is about 5 mm. [centimeters. R. R. G.]. The branches are half a millimeter thick. The rudimentary branchlets, irregularly situated, are seldom more than 2 mm. long, and are stout, while the spinelike processes have a length of half a millimeter, and are about the same distances apart, being very slender.

The branches of this exceedingly beautiful frond (as I have only one complete specimen) appear to have occupied a semicircular position when alive, but in

compression has so fallen as to extend nearly in the form of a circle. Though it resembles somewhat *Callograptus niagarensis*, yet the numerous rudimentary branchlets and spinelike processes distinguish it from that species.

Formation and locality.—This species is found in the "chert-beds" of the Niagara formation at Hamilton, Ontario. The best specimen was obtained from Mr. Edward McLaughlin, of Hamilton.

Gurley's notes on this species follow:

To this species I have referred, in all, sixteen specimens, several of the more fragmentary ones with some doubt. One specimen (Pl. 4, fig. 5, text fig. 82) shows the base, and may be described as follows:

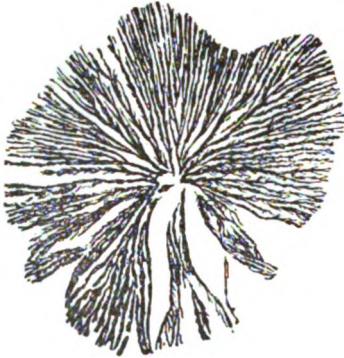


FIG. 81.—*ACANTHOGRAPTUS PULCHER* SPENCER. COPY OF SPENCER'S FIGURE.

Polypary (in this specimen) semicircular-fanbelliform, originating in, and sessile upon, a transversely extended, apparently thick, fibrous, or discoid base of a black carbonaceous texture. From the base arise about three main branches, which bifurcate and rebifurcate in their course toward the periphery, the resulting somewhat wavy branches running nearly straight out to the periphery, where they seem to terminate in two or several twigs or spikelets. Along their course their sides are beset with "rudimentary branchlets," etc., whose length may reach 1 mm. In this species, however, these lateral fringing processes are fine, giving the branches a

feathered appearance. They never reach the thickness and remoteness of those seen in *A. walkeri*. The usual width of the branches is 0.4 mm., but some reach 0.5 mm. About 40 branches occur in 25 mm. of width, the interspaces thus being quite narrow. Only two these are visible. These are 0.4 mm. apart (corresponding to about 60 in 25 mm.). Indications of dissepiments are not wanting (some structures very much like them are visible), and although not entirely willing on strength of the present material, I may say that I incline very strongly to doubt their asserted absence in any of these genera, and also that in my opinion there is hardly a more dubious character than "absence of dissepiments." For the assertion of such a condition the material must be absolutely irreproachable, as of all the structures in the polypary the dissepiments, being the most delicate, are the first to disappear.

There can, I think, be no doubt that the present form is Spencer's species. Both as a diagnosis by exclusion, and by its general agreement with his description and figure, its identity is satisfactorily made out.

Horizon and locality.—Niagara chert and glaciated chert, Hamilton, Ontario.

Plesiotypes.—Cat. No. 55307, U.S.N.M.



FIGS. 82, 83.—*ACANTHOGRAPTUS PULCHER* SPENCER. 82, SPECIMEN PRESERVING BASE. (SEE ALSO PL. 4, FIG. 5); 83, LESS COMPLETE RHACHIDOSOME.

ACANTHOGRAPTUS CHAETOPHORUS Gurley, new species.

Plate 3, figure 5.

Gurley's description is as follows:

Polypary consisting of several main stems which may reach a thickness of 0.4 mm.; but principally characterized by very numerous, excessively fine, hair-like, more or less tufted fibers which fringe the sides of the stems and (?) also arise freely from the (invisible) base. These appear to be present, but are indistinct.

This species unquestionably finds its nearest affinity in *Acanthograptus*. It can hardly be a *Dendrograptus*, if that term be limited to forms taking origin from a single stem, as the form renders it very probable that it grew in tufts from a transversely extended base.



FIG. 84.—ACANTHOGRAPTUS CHAETOPHORUS, NEW SPECIES. HOLOTYPE. (SEE ALSO PL. 3, FIG. 5.)

Horizon and locality.—Niagara dolomite, Hamilton, Ontario.

Holotype.—New York State collection.

ACANTHOGRAPTUS MULTISPINUS Gurley, new species.

The description by Gurley is as follows:

Polypary flabellate-compressed, originating in and sessile upon a black, carbonaceous, discoid base, from which the main branches arise, and then divide and subdivide, run outward, spreading somewhat to both sides and being somewhat undulate; 0.3–0.4 mm. wide; set about 25–30 in 25 mm. of width; their sides beset with processes of variable length and closeness. These processes are in character intermediate between those of *A. walkeri* and those of *A. pulcher*, being stouter, more rigid, and more distant than in the latter species, but less stout, less rigid, and closer together than in *A. walkeri*. Their lengths and closeness are too variable to be well reduced to measurements.



FIGS. 85, 86.—ACANTHOGRAPTUS MULTISPINUS, NEW SPECIES. TWO TYPE-SPECIMENS. (FIG. 85 BY R. S. BASSLER.)

The present species most nearly resembles *A. pulcher*, but in general has the branches more divergent, and with less tendency to parallelism; the fringing processes are stouter, more rigid, and more distinct, and the resulting appearance is less finely feathery.

Horizon and locality.—Niagara chert, Hamilton, Ontario.

Cotypes.—Cat. No. 55309, U.S.N.M., and New York State collection.

Genus THAMNOGRAPTUS Hall.

Thamnograptus HALL, Rep. Progr. Geol. Surv. Canada for 1857, 1858, p. 143, *nomen nudum*; Nat. Hist. New York, Pal., III, 1859, 1861, p. 519; 13th Rep. New York State Cab. Nat. Hist., 1860, p. 62; Can. Org. Rem., Decade 2, 1865, p. 141; 20th Rep. New York State Cab. Nat. Hist., 1868, p. 218 (rev. ed., 1868 [1870], p. 251).—NICHOLSON, Mon. Brit. Graptolites, 1872, p. 130; Ann. and Mag. Nat. Hist. (4), XVI, 1875, p. 270.—ZITTEL, Handbuch d. Pal., I, 1879, p. 290.—SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 563, 589; Bull. Mus. Univ. State Missouri, I, 1884, p. 39.—MILLER, North Amer. Geol. and Pal., 1889, p. 207.—POCTA, Syst. Sil. Centre Boheme, VIII, Pt. 1, 1894, p. 165.—ELLES and WOOD, Mon. Brit. Graptolites, Pal. Soc., 1903, p. xli.—RUEDEMANN, New York State Mus., Mem. 11, 1908, p. 204.

This peculiar genus was founded upon two Ordovician species of graptolites, which have recently been studied by Ruedemann. The absence of thecæ or apertures upon the branches has always kept the genus doubtful, and the following descriptions of the Niagaran forms can not be said to add anything to the knowledge of the genus.

The original diagnosis is:

Bodies consisting of straight or flexuous stipes (simple or conjoined at base?) with alternating and widely diverging branches; branches long, simple or ramose, in the same manner as the stipe. Substance fibrous or striate; the main stipe and branches marked by a longitudinal central depressed line, indicating the axis. Cellules or serratures unknown.

Genotype.—*Thamnograptus typus* Hall (= *Thamnograptus capilaris* Emmons). Normanskill shale, Kenwood, near Albany, New York.

THAMNOGRAPTUS BARTONENSIS Spencer.

Thamnograptus bartonensis SPENCER, Canadian Nat., VIII, 1878, pp. 458, 462. *Thamnograptus bartonensis* SPENCER, Trans. Acad. Sci. St. Louis, IV, 1884, pp. 565, 589, 590, pl. 6, figs. 4, 5; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 39, 40, pl. 6, figs. 4, 5.—GURLEY, Journ. Geol., IV, 1896, pp. 101, 309.

The original description follows:

Stipes single and broad with lineal undulating branches alternately arranged on opposite sides and having half the thickness of the stipe, which is as much as one-sixteenth of an inch broad. The branches which are given off are usually at right angles with the stipe; and are generally half an inch apart: there being an undulation of considerable length opposite to their place of attachment.

Texture corneous and black, the surface being nearly smooth with longitudinal depressions. The branches are usually short and abrupt.

They occur in the Niagara Limestone at Hamilton, Ontario, and the writer has seen them in the rock several inches long.

Quoting from Doctor Gurley's manuscript:

The description of 1884 adds: Branches having half the thickness of the stipe, their bases nearly at right angles with it, but afterwards they bend up-

ward; inserted on the stipe 1 to 2 cm. apart. At point of origin there is usually a depression of considerable length on the side opposite to their place of attachment, and an expansion on the same side. There is a strong medial depression, 0.5 mm. wide (marking a central axis?), extending through the stipe, which is 1.5 mm. broad.

The specimens obtained are not entire. The branches are often widely separated, and are sometimes long and flexuous, extending for several centimeters in length. It sometimes happens that we obtain a long stipe which may be either a portion of the structure below the branches or a portion of a separate branch.

Doctor Gurley further remarks:

Altogether there are 9 specimens which I refer to this species. They vary considerably and tend to arrange themselves in two series, and at different stages in my work I have rated them as separate species and as separate varieties. The latter is still the course I should prefer, if I could with any confidence correlate the two series in any definite way^a with Spencer's species. But as I can not do so satisfactorily, they are simply characterized as well as possible, and the task of connecting or separating them must remain to be worked out in the light of more complete specimens. I might, however, add that though there is no certainty in the matter I rather incline to believe these two series to represent widely separate fragments of the same polypary.

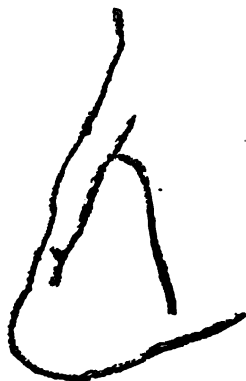


FIG. 87.—THAMNOGRAPTUS
BARTONENSIS SPENCER.
COPIED FROM SPENCER.

Series A.

Polypary (?) consisting of long, more or less straight, or flexuous stems, 1.25–2.5 mm., which for long distances are simple and destitute of branches. In the five specimens (on three slabs) plainly referable to this series, only two branches are seen. These branches are about 1 mm. wide, and diverge from the main stem at about 60° or a little less. Texture brown-black, carbonaceous, exactly similar to that of *Inocaulis plumulosa* in the same beds.



FIGS. 88, 89.—THAMNOGRAPTUS BAR-
TONENSIS SPENCER. TWO FRAG-
MENTS BELONGING TO SERIES B.

Series B.

Main stems and branches much narrower than in series A (stem *ad maximum*, 1.5 mm., usually 0.8, occasionally 0.6 mm. wide; branches mostly 0.5–0.8 mm. wide); branches more numerous, tending to diverge at a right angle or a little less. Texture the same as in series A.

The specimens referred to series A belong to the Spencer collection and are not accessible at present. Those of series B are represented in text figures 88 and 89.

^a *E.g.*, both with all of Spencer's species, or either with any definite part thereof. I might perhaps add that a correlation of Series A with Spencer's fig. 4, and of Series B with his fig. 5, seems somewhat plausible.—R. R. Gurley.

Horizon and locality.—Niagaran (Lockport). Hamilton, Ontario.
Plesiotypes.—Cat. No. 55318, U.S.N.M.

THAMNOGRAPTUS (?) MULTIFORMIS Spencer.

Thamnograptus (?) *multiformis* SPENCER, Canadian Nat., X, 1882, p. 165, *nomen nudum*; Trans. Acad. Sci. St. Louis, IV, 1884, pp. 585, 590, pl. 6, figs. 2, 3; Bull. Mus. Univ. State Missouri, I, 1884, pp. 15, 40, pl. 6, figs. 2, 3.—GURLEY, Journ. Geol., IV, 1896, p. 101.

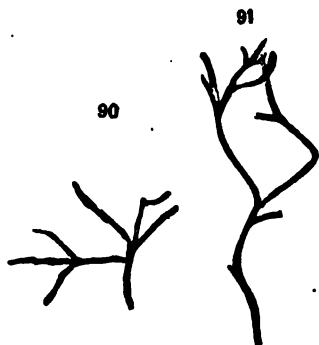
The original description is as follows:

Stipes simple, flexuous, and strong, usually divided into two (sometimes three) branches of equal thickness. From both the undivided and divided stipe a few short irregular branches originate at long unequal distances apart; and these may or may not end in two free points. The texture is corneous and black,

with the surfaces somewhat striated and impressed with a medial line (indicating a central axis?). In occasional specimens of the same mode of branching, short spinelike processes, from one-half to one millimeter long and half a millimeter apart, probably indicate the position of the cellules on both sides of the branches.

There is considerable variation in the size of these organisms. The larger specimens are 4 or 5 cm. long, and the stipes are usually about 1 mm. thick; however, some of the specimens, that I have referred here, have not more than half that size. In the larger specimens the branches are usually about half a centimeter apart.

FIGS. 90, 91. — THAMNOGRAPTUS ?
 MULTIFORMIS SPENCER. COPIES
 OF SPENCER'S FIGURES.



In the rocks of the Niagara formation numerous fragments of organism of the graptolite family occur. Vast numbers, consisting of thick broken stipes, often flexuous, with one or two branches, or those with dichotomous terminations, are found, and can not be referred to any species described. Yet they so closely resemble the better specimens of this species that I have placed them here, although a further study might separate some of them from this species.

Formation and locality.—Fragments of this species occur somewhat abundantly in the Niagara dolomitic rocks at Hamilton, Ontario.

Of this species Doctor Gurley says:

After many endeavors to recognize this species I have failed to find anything which I could confidently refer to it. As far as my experience goes nothing which has any definite structure resembles it. The only things which seem to approximate it are the most fragmentary specimens, too indefinite to be referred anywhere else. A perusal of Spencer's description also leads me to suspect (but I do not assert it) that this species is not much more than a dumping ground for fragments. Certain it is that from time to time series after series of fragments (and at this horizon fragments are unusually and disproportionately numerous) otherwise unplaced were identified as this species, but eventually all except the worst were successfully referred elsewhere. This species must then stand on Spencer's diagnosis and figure.

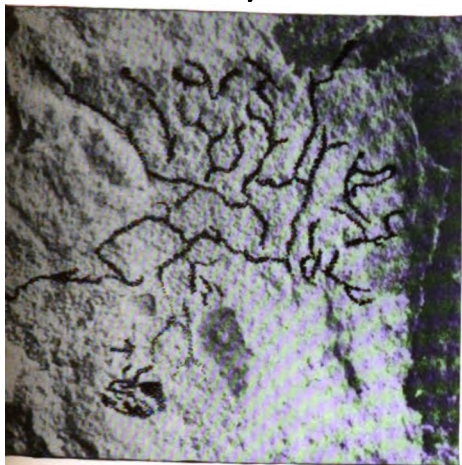
DESCRIPTIONS OF PLATES.

Unless otherwise stated, the views shown on these plates were prepared by R. S. Bassler.]

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2. A larger example, $\times 1.5$, showing the lax arrangement of the branches.	
3. <i>Dendrograptus ramosus</i> Spencer.....	
(See also text figs. 3 and 9.)	
Gurley's photograph of the specimen, $\times 1.5$, illustrated on page 7.	
4. <i>Dendrograptus ontarioensis</i> , new species	
(See also text fig. 12,)	
The type-specimen, $\times 2$.	

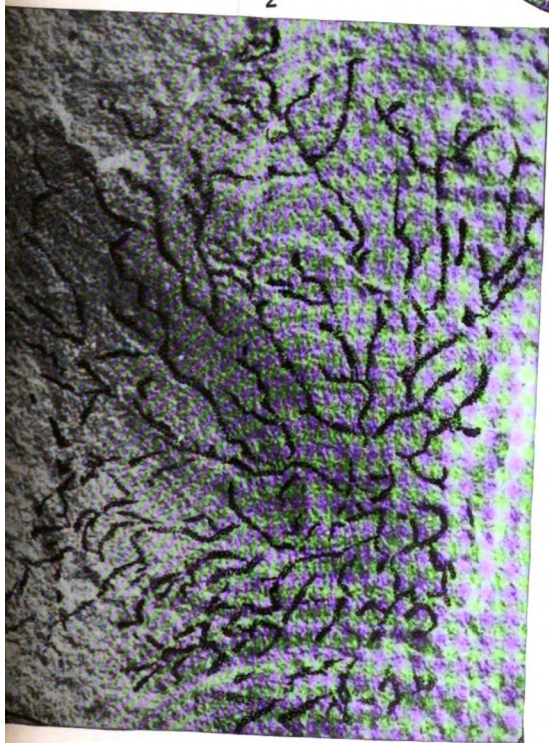
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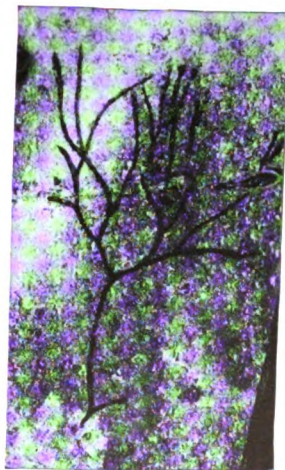
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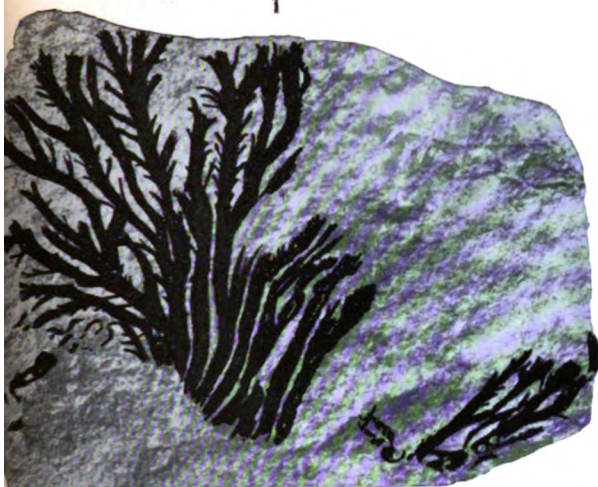


NIAGARAN GRAPTOLITES.

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A retouched photograph of the type-specimen, $\times 3$.	
3. <i>Dendrograptus praegracilis</i> Spencer	
(See also text figs. 4 and 10.)	
Photograph of the specimen illustrated in text fig. 10.	
4. <i>Dirtynema tenellum</i> Spencer	
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5. <i>Inocaulis</i> ? <i>thallosus</i> , new species	55
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Photograph of the type-specimen, $\times 1.5$, by Gurley.	

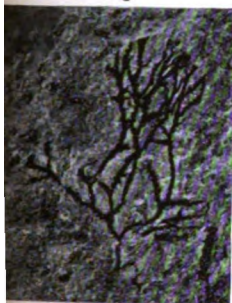
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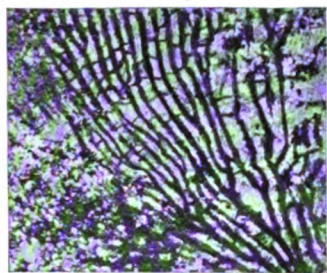
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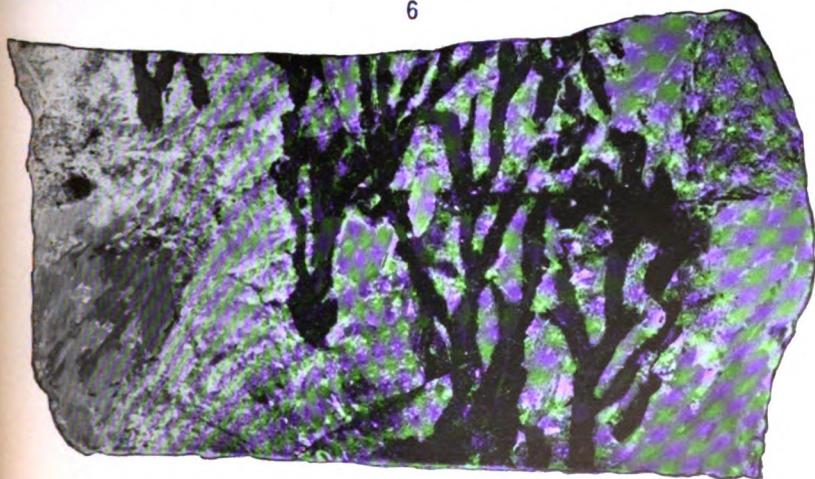
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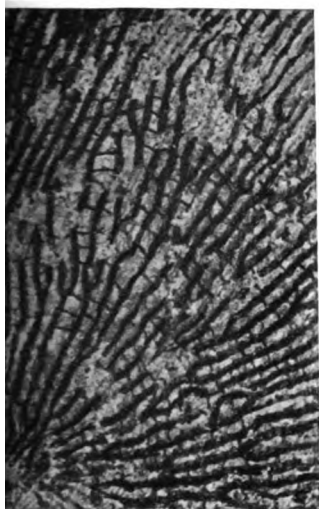
NIAGARAN GRAPTOLITES.



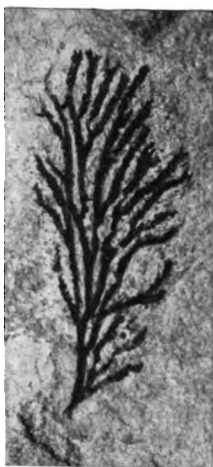
EXPLANATION OF PLATE 3.

- Fig. 1.** *Dictyonema crassibasale*, new species.....
 (See also text figs. 21-25.)
 A portion of the rhabdosome, $\times 2$, figured in text fig. 23.
- 2.** *Dictyonema stenactinotum*, new species.....
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 View of the specimen, $\times 1.5$, illustrated in text fig. 35.
- 3.** *Callograptus strictus*, new species.....
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 The type-specimen, $\times 2$.
- 4.** *Acanthograptus granti* Spencer.....
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 Photograph by Gurley, with rhabdosome retouched in black.
- 5.** *Acanthograptus chaetophorus*, new species.....
 (See also text fig. 84.)
 Photograph of the type specimen, $\times 1.5$.

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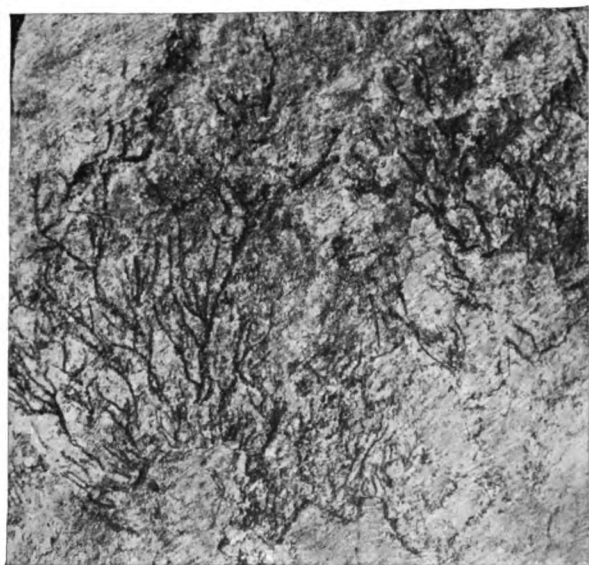
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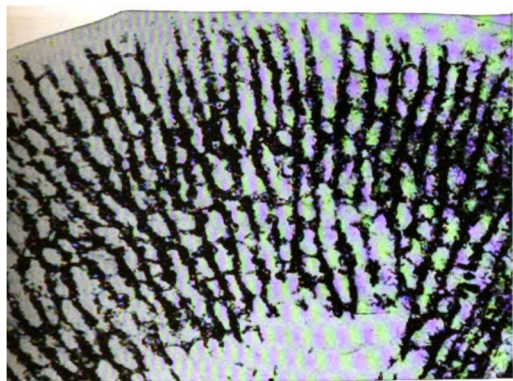


NIAGARAN GRAPTOLITES.

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5. <i>Acanthograptus pulcher</i> Spencer.....	59
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View of a rhabdosome, $\times 2$, preserving the base.	

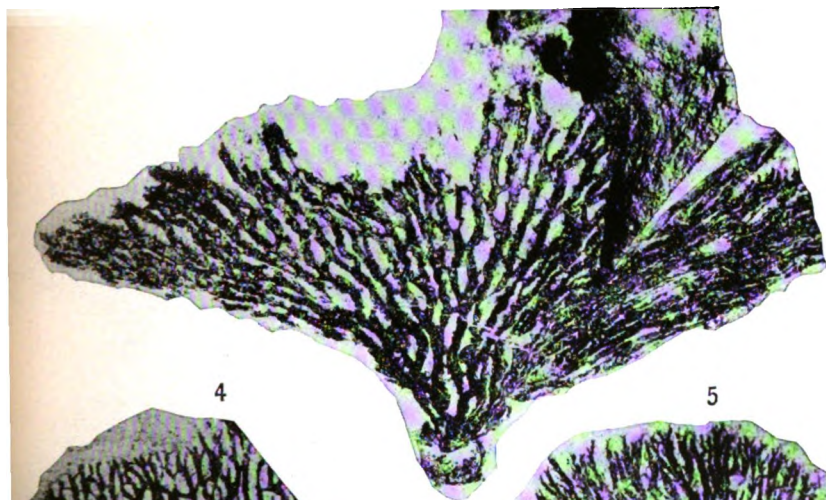
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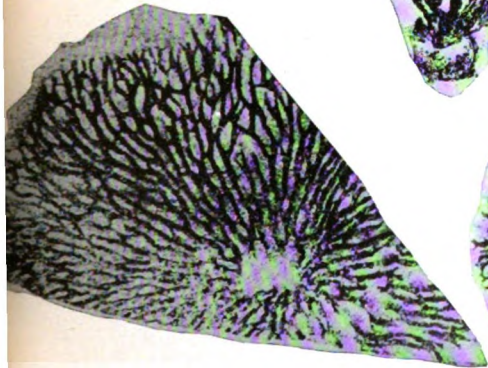
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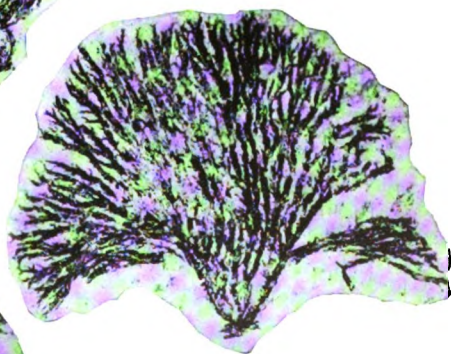
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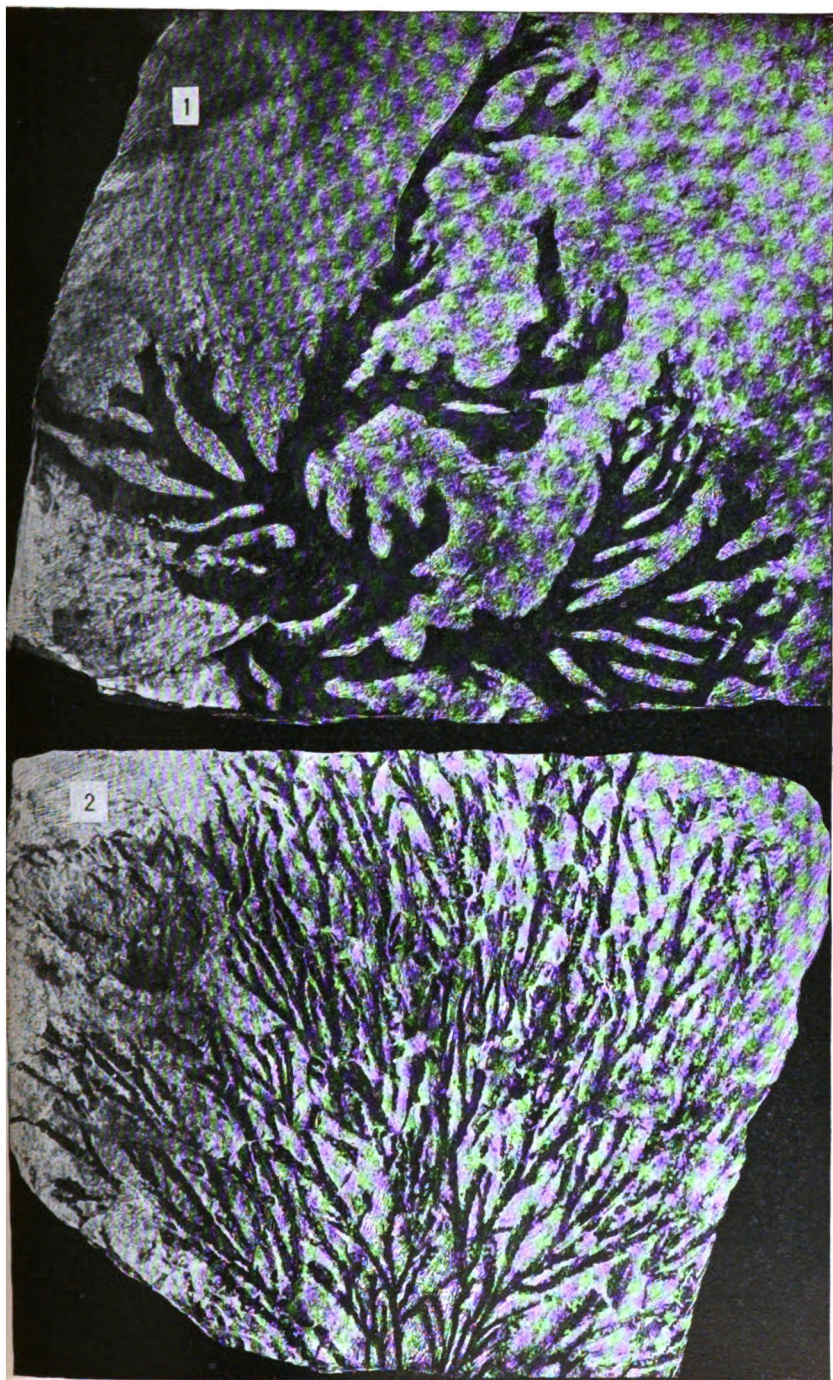


NIAGARAN GRAPTOLITES.



EXPLANATION OF PLATE 5.

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A retouched photograph of the type-specimen, natural size.	
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Photograph of the type-specimen, natural size.	



NIAGARAN GRAPTOLITES.

INDEX OF GENERA AND SPECIES.

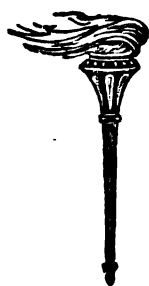
[Synonyms are in *italics*. Numbers in heavy-faced type indicate the pages where descriptions are to be found.]

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JR. KEMP WELCH,



Proceedings of the Paleontological Society

CONFERENCE ON THE FAUNAL CRITERIA IN PALEOZOIC
PALEOGEOGRAPHY

BY

R. S. BASSLER, SECRETARY

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CONFERENCE ON THE FAUNAL CRITERIA IN PALEOZOIC
PALEOGEOGRAPHYR. S. BASSLER, *Secretary*

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INTRODUCTION

The Council of the Paleontological Society voted that at the Second Annual Meeting, held at Pittsburgh, that the greater part of one day should be given to a conference on the faunal criteria of use in paleogeography for the discerning at what probable depth the Paleozoic sediments were deposited, the shorelines of such deposits, the temperature of the water, the factors indicating faunal provinces, and the effect of currents on the life assemblages. To this end the President of the Society, Prof. Charles Schuchert, secured the cooperation of a number of paleontologists, each one being well versed in the topic selected, and December 29, 1910, was selected for the presentation of papers. As the time limit set for each paper was short, the participants could not always give the desired detail on which their conclusions were based.

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NATURE OF TERTIARY AND MODERN MARINE FAUNAL BARRIERS AND CURRENTS¹

BY WILLIAM H. DALL

Were the earth evenly covered with water of a uniform depth and density, or the dry land confined to circular zones of which the center coincided with the axis of the earth's rotation—in other words, with the poles—it would be mathematically possible to compute the extent and course of the marine currents. An approximation to such a computation for the earth's atmosphere has been made by Ferrel and subsequent writers on meteorology, but the smooth theoretical atmospheric circulation of theory is much interfered with by the actual asperities of the earth's surface and by differences in temperature and density, in a vertical sense, due to the influence of the sun's rays.

To such an extent as the emerging continents became physical barriers to the oceanic circulation demanded by theory, the course of currents and incidentally their density and temperature have become modified. The north and south extension of the continents and the various directions taken by their eastern and western shores have so complicated the whole problem that a thorough demonstration of the facts involved, even for limited areas of coast, is in most cases still to be attained. Still, the broad outlines of distribution of marine currents and their temperatures are fairly well known. We have learned that the temperature of the sea in which they live, within certain narrow limits, controls the distribution of marine invertebrates. Whatever the tolerance they may exhibit, and different species differ in this respect, there are distinct boundaries set to their distribution in the differences of temperature brought about by the circulation of oceanic waters. Whether these differences limit the range of faunas by direct action on the individuals or by their effect on the development of their progeny or by limiting their normal food supply has not yet been demonstrated; but it seems quite certain that in the larval stages the young invertebrates are markedly more susceptible to differences of temperature than adult animals, and, in the case of the oyster, Brooks found that a difference of two or three degrees Fahrenheit in the temperature of the water was sufficient to kill the whole larval brood. By inhibiting natural increase, therefore, a species may be as sharply limited in its permanent range as if material barriers interposed.

¹ Manuscript received by the Secretary of the Society May 23, 1911.

There are two principal ways in which the sea temperature of a given region may be decided, apart from the normal amount of direct heat it may receive daily from the sun. One of these is due to the invasion of a region by an oceanic current, properly so called (that is, a body of water with motion in a definite direction usually differing from the sea about it in temperature, and more or less distinctly laterally limited), analogous to a river on a land surface in its relation to the adjacent sea. Such a current may carry cool water into a warmer region, or warm water into a cooler region, and by the temperature and evaporated moisture it gives off may also alter the aerial and terrestrial climates of the region invaded. Such examples as the Gulf Stream or the Equatorial current will occur to every one reflecting on the subject.

The rate and direction of such currents are determined, first of all, by the friction of the trade winds on the surface of the sea; secondly, by the land barriers encountered, and to a less extent by barometric pressure, differences of density due to concentration of saline matter and other minor factors.

The other way in which sea temperatures are affected is due to oceanic circulation independent of the friction of the winds, and which would occur if there were no winds at the surface of the sea. The rotation of the earth causes a lagging of the surface waters and a welling up on the western shores of continents of colder bottom waters when the contour of the sea bottom is favorable. The evaporation from surface waters in the tropics increases the salinity and density of the water affected, and there is a constant interchange of less dense cold polar waters with those of the tropics. The waters of the deeps are nearly always of polar temperature. The movements of the tides impinging on continental shores aid in this system of circulation.

It does not seem possible, under conditions of atmosphere approximating those of the present time, that there should ever have been a time when the tropic seas were not perceptibly warmer than the polar waters, though the latter may have been much warmer than at present. As soon as marine animals developed to a stage where temperature became a factor in their physiological history, it was inevitable that faunas should develop, and the more susceptible the inhabitants of the sea became the more distinctly faunas would become limited.

Of course, the development of the food supply, itself dependent on the sea temperature, the presence of large bodies of fresh water at the mouths of great rivers, the evolution of destructive gases arising from the sea bottom, or the invasion of limited areas of sea by noxious salts derived

from land areas, or submarine plutonic action altering the temperature or the chemical constitution of the sea water locally—all might at times have a temporary influence of some importance, but necessarily of a trifling kind compared with the two chief factors above mentioned, the currents and the oceanic circulation due to permanent cosmic causes of the first order of magnitude.

When we find the shore fauna of the eastern coast of South America practically the same on the shores north and south of the Amazon estuary we conclude that the distribution of the fauna antedates the existence of the estuary. When we find the boreal fauna extending down the eastern coast of North America, with representatives as far south as Georgia, we infer, what is proved by hydrographic investigation, that the Polar current is represented by an inshore band of cold water. We find on the Pacific coast of America the Oregonian fauna coinciding in distribution with the divaricating branches of the North Pacific current; the Peruvian fauna with those of the Humboldt or Peruvian current; on the Asiatic coast the Kuro Siwo and the Japanese fauna, the Okhotsk fauna and the Kamchatka current, are practically coincident. All over the world the close association of the range of temperature-bearing waters and marine faunas is recognizable, though occasionally less clear on account of the intervention of land barriers or minor causes.

When sudden changes of faunal characteristics occur in successive fossil faunas in the Tertiary, as at the end of the Oligocene and the beginning of our Chesapeake Miocene in the southern part of our coastal plain, though no orographic changes or unconformities appear on the spot, we are justified in concluding that changes at a distance have taken place which have altered the course of ocean currents and consequently have brought about local changes of temperature.

If it be possible to lay down with approximate accuracy the distribution of land at no matter what distance of geologic time, an application of the principles governing the distribution of ocean currents and the circulation of oceanic waters should enable the geologist to map the approximate distribution of the marine faunas at that epoch, always provided the difference of sea temperatures between the tropics and the Polar sea was at that period sufficient to affect organic life then existing in the ocean.

VALUE OF FLORAL EVIDENCE IN MARINE STRATA AS INDICATIVE OF
NEARNESS OF SHORES¹

BY DAVID WHITE

In discussing, from the paleogeographic standpoint, the occurrence of plants in limestones or other marine sediments primary consideration must scrupulously be given, first, to the kind of plants, and, second, to the condition of the plants.

In illustration of the first of these considerations it is hardly necessary to remark that algæ of marine types, though they may be blown along the beach and into coastwise dunes, are not likely to find a place in epicontinental fresh-water basins nor, except in the rarest instances, in eolian desert deposits. Neither, on the contrary, should one look in fresh-water coal basins for salt-marsh vegetation. So, also, though he may discover fresh-water limestones, which directly owe their very being to fresh-water algæ, one should not expect to find sweet-water thallophytes composing limestones in a marine environment. Each limestone contains calcareous or other algæ of its own kind. Otherwise do "men gather figs of thistles."

In practice, however, and for general paleogeographic uses algæ are apt to be of little need, or if needed they frequently are of little help, so very imperfect is our paleontologic knowledge of the small calcareous rock-building types, and so poorly preserved are usually the others whether in rocks of organic or terrigenous origin. Therefore, in the present discussion, further consideration will be confined to land plants; and, since the question is one of geographic values, to vascular only. This brings us, in our weighing of fossil plant criteria, to the second important point, namely, the condition of the plants themselves.

The occurrence of remains of land plants in limestone is uncommon enough always to attract the attention of the geologist, but the discovery of well preserved specimens, especially leaves, in a limestone formation is so exceedingly rare as never to fail to excite comment. In fact finding good specimens of land plants in the company of marine invertebrates in any place is worthy of mention, regardless of the sedimentary circumstances.

It is worth while in this connection to give brief attention to the conditions now to be observed and the processes now in operation in the seas of the present day. The reports of the *Blake*, the *Challenger*, and the

¹ Manuscript received by the Secretary of the Society May 28, 1911.

Albatross show that in certain regions of terrigenous deposits, especially within the tropics, vegetal refuse is abundant on the ocean bottom, even at depths of more than 2,000 fathoms. Thus Agassiz states that

"While dredging to the leeward of the Caribbean Islands, we could not fail to notice the large accumulation of vegetable matter and of land debris brought up from deep water many miles from the shore. It was not an uncommon thing to find at a depth of over one thousand fathoms, ten or fifteen miles from land, masses of leaves, pieces of bamboo and of sugar-cane, dead land shells, and other land debris, undoubtedly blown out to sea by the prevailing tradewinds. We frequently found floating on the surface masses of vegetation, more or less water-logged, and ready to sink. The contents of some of our trawls would certainly have puzzled a paleontologist; between the deep-water forms of crustacea, annelids, fishes, echinoderms, sponges, etcetera, and the mango and orange leaves mingled with branches of bamboo, nutmegs, and land shells, both animal and vegetable forms being in great profusion, he would have found it difficult to decide whether he had to deal with a marine or a land fauna. Such a haul from some fossil deposit would naturally be explained as representing a shallow estuary surrounded by forests, and yet the depth might have been fifteen hundred fathoms. This large amount of vegetable matter, thus carried out to sea, seems to have a material effect in increasing, in certain localities, the number of marine forms."

The descriptions of the bottom deposits explored by the *Challenger*¹ mention the occurrence of twigs, woods, and seeds at a depth of 800 fathoms near Ki Islands, and the presence of twigs and leaves within 20 fathoms off the coast of Amboina Island, both localities being west of New Guinea. Palm fruits and fragments of wood and bark were found at a depth of 2,150 fathoms in the group of islands south of Mindanao, and fragments of leaves, stems, and wood, the latter overgrown with *Serpula*, were dredged from a depth of 1,050 fathoms at a station about 50 miles off the west coast of Luzon.

Agassiz, in his account of the explorations of the *Albatross* off the west coast of Central America, notes that:

"A very fine mud was the characteristic bottom we brought, often very sticky, and enough of it usually remained in the trawl, even when coming up from depths of 2,000 fathoms, materially to interfere with the assorting of the specimens contained in our hauls. This mud continued all the way from the Galapagos to Acapulco, and up to the mouth of the Gulf of California, where it became still more of an impediment to dredging, so that little work was done until we passed the Tres Marias. Even then the trawl was ordinarily well filled with mud, and with it came up the usual supply of logs, branches, twigs, and decayed vegetable matter.

¹ Bull. Mus. Com. Zool., Harvard Coll., vol. xiv, p. 391.

² Deep-sea deposits, pp. 95, 97, 99, 101.

"On going farther north, into the Gulf of California, the nature of the bottom did not change materially from what it had been along the coast from Acapulco to Cape Corrientes; it was the same viscid mud, mixed occasionally with *Globigerina* and masses of vegetable matter. So we found the trawling most difficult from the weight of the mud brought up, but occasionally a haul was made which more than repaid us for the time spent on the less productive ones.

"In the dredgings of the *Blake* in the Gulf of Mexico, off the West Indies, and in the Caribbean, my attention had already been called to the immense amount of vegetable matter dredged up from a depth of over 1,500 fathoms on the lee side of the West India Islands. But in none of the dredgings we made on the Atlantic side of the Isthmus did we come upon such masses of decomposed vegetable matter as we found on this expedition. There was hardly a haul taken which did not supply a large quantity of water-logged wood, and more or less fresh twigs, leaves, seeds, and fruits, in all possible stages of decomposition."

In another account he refers again⁶ to the abundance of water-logged wood, leaves, seeds, etcetera, "in all possible stages of decomposition," adding that "this was especially noteworthy in the line from the mainland to Cocos Island." On that portion of the cruise extending across the Humboldt current from the Panama coast to the Galapagos Islands Agassiz observed⁷ that a few fragments of leaves were obtained at a depth of over 1,700 fathoms at a point nearly half way between Cape San Francisco and the Galapagos Islands.

With reference to the volume of terrigenous deposits Agassiz remarks:⁸

"From the investigations made this year by the *Albatross*, I am more inclined to assume that the true cause of the absence of coral reefs on the west coast of Central Africa is due to the immense amount of silt which is brought down the hill and mountain sides every rainy season, and which simply covers the floor of the ocean to a very considerable distance from the land, the land deposits being found by us even on the line from the Galapagos to Acapulco at the most distant point from the shore to the side or extremities. The mud in Panama Bay to the hundred-fathom line is something extraordinary, and its influence on the growth of coral reefs is undoubtedly greatly increased from the large amount of decomposed vegetable matter which is mixed with the terrigenous deposits."

Again, in his notes on the exploration of the Gulf of California, we find that⁹ "the trawl was usually well filled with mud," and that "the mud gave up the usual supply of logs, branches, twigs, and decayed vegetable matter."

⁶ Bull. Mus. Comp. Zool., Harvard Coll., vol. xxiii, p. 12.

⁷ Op. cit., vol. xxi, 1891, p. 187.

⁸ Loc. cit., p. 190.

⁹ Loc. cit., p. 195.

¹⁰ Loc. cit., p. 197.

While the striking instances cited from the reports just mentioned^{*} are important as showing both the distance to which vegetal refuse may, under favorable circumstances, be deposited, and the depth at which it may be found in terrigenous deposits, two important points should not be lost from view: first, that most of the material is found in regions of deposition of terrigenous matter, and, second, that in most cases the localities are in close proximity to the land. Even in the latter cases the organic matter is described as more or less decayed, while in the most remarkable series, extending over a stretch of 500 miles or more from the Central American coast to the Galapagos Islands, we find that all the material was "in varying stages of decomposition." At best the leaf fragments reported appear to have been confined to types with hard, siliceous, or thick cuticles, such as the palm and the bamboo. Only thick, leathery, dicotyledonous types like the orange and the mangrove seem to have been in recognizable condition in the dredging near the land. Only in very rare cases do we find any quantity of land plant material under the conditions of deposition of the purer carbonates at any considerable distance from the coast, and in these cases the material embraces only the more imperishable parts of the plants.

The significance of the evidence offered by plant remains found fossil in marine deposits depends mainly on the state of their preservation. If the material is macerated, corroded, rolled, defoliated, skeletonized, incrustated, or bears other signs of having been for some time in the water, it is liable to have been transported for some distance, judgment of the possible distance or time being dependent to an extent on the progress of the work of the destructive agencies. If long in sea water the fragments are likely to bear the marks of the abundant marine organisms, particularly if in tropical sea water. On the other hand, the occurrence of clean, unbroken, smooth leaves, and particularly of large segments of fern fronds, with their full complement of carbonaceous residues, is *prima facie* evidence of minimum exposure to water and of the least subjection to the action of swift currents or waves. In fact, it may be stated that except in extraordinary or most fortuitous cases clean and distinct leaves are never found in limestone strata, whether marine or fresh water, except in a very near relation to the land on which they had origin. Farther from land they are more indistinct, poorly preserved, fragmentary and deformed, as well as wasted. In most marine sediments the only vestiges of land plants that may be found are confined to the most indestructible

^{*} For illustrations of long transportation see Lyell: *Principles of geology*, 1867, vol. II, p. 361; vol. I, p. 445; *Challenger* narrative, vol. I, pt. 2, p. 679; Bates: *Naturalist on the River Amazon*, 1868, p. 389.

parts—that is, seed envelopes, spore covers, pollen shells, and fragments of wood and stems, especially of resinous or very dense types. This is due to several causes:

1. On account of their fragility leaves, especially those of ferns, are very quickly rumpled, curled, torn, or shredded in water transport, and if long en route are soon reduced to fine refuse (“Häcksel”) by wind, wave, or current action. Leaves become submerged sooner than trunks, twigs, etcetera; they are promptly attacked by the pelagic animal life, and their mesophyll quickly decays as the result of microbial action.

2. On reaching salt water they are very quickly covered by slimes, animal and vegetal organisms, which coat or corrode the surface, so that unless buried promptly they can not leave clean or clear-cut imprints, even if submerged beneath cold waters. The observations of several marine naturalists go to show that signs of the destructive agencies, exclusive of wave and current, are generally evident in less than two days from the moment of marine submersion.

3. Decay proceeds more rapidly in salt than in fresh water, by reason of the abundance and variety of the attacking animal types, and also, it is said,¹⁰ on account of the greater amounts of sulphates and carbonates in sea water, which by decomposition in the presence of organic acids facilitate the oxidation (destruction) of the plant tissue. Decay proceeds even at great depths and in low temperatures; but these are regions of slow deposition, so that there is correspondingly greater time for corrosion and putrefaction, or even total destruction, before the organic matter becomes protected by an oxygen-excluding sedimentary cover.

4. The conditions of open marine deposition preclude the development of a partial or completely aseptic or toxic water-cover, such as may take place in fresh or land-locked water bodies.

5. Regions of distinctly calcareous deposition, or of limestone formation—that is, regions comparatively free from terrigenous sediments—are apt to be far from the mouths of rivers and from currents carrying land sediments, therefore plants are not likely to reach them in good condition unless the deposits are close to shore or coast. If rapidly transported they are liable to damage by wave action and other commotion of the current. Furthermore, in most regions of such sedimentation the accumulation of the rock-forming material is so slow that the most enduring parts of the plants may seldom escape decay before they are so far buried as to make permanent their forms.

The fresher the vegetal material the better the chances that some por-

¹⁰ *Challenger* reports: Deep-sea deposits, p. 256.

tion of it may leave a recognizable impression; or, again, the greater the influx of terrigenous matter, including vegetal debris, with consequently more rapid sedimentary deposition, the more likely the burial of a part of the plant refuse in recognizable condition.

It would appear that the areas of most abundant terrigenous muds, with plant ingredients, between Central America and the Cocos or the Galapagos Islands, are regions of deposition of somewhat carbonaceous shales, probably more or less calcareous in certain districts, and possibly comparable to those of the Upper Devonian in portions of Ohio. They contain the raw materials for the petroleum and natural gas of a future geologic age, when portions of partially decayed plant refuse in the region of the western Pacific Islands will be found in calcareous shales or shaly ferriferous or manganiferous limestones.

If, now, we turn to examine the geological conditions attending the occurrence of well preserved plants in limestones or other clearly marine strata of geologic age, we find that in nearly every case of reasonably good preservation of leaf or fern material there is associated geologic evidence of the existence of land not far distant. The best preserved filicoid types of the Ithaca group are associated with contemporaneous channel cutting and other local shoal water phenomena. The relatively well preserved material in the Portage (Hatch), near Naples, New York, is said to be associated with coaly streaks, which I regard as indicative of probable local flats or possibly a partially land-locked or temporarily lagoonal environment. The splendid *Archæopteris* fronds of the Catskill and Chemung in southern New York and northeastern Pennsylvania are in most cases stratigraphically associated with contemporaneous erosion planes, truncated mud beds, carbonaceous wedges, breccias or conglomerates—all indicative of subaerial exposure or approximate littoral conditions. So, also, with the better grade of material from the Burgoon and the lower Pocono. The floras in the Canaan limestones of the Buckhannon quadrangle in West Virginia, in the Bluefield shale formation at Abbs Valley, in southwest Virginia, and in the Bangor of Alabama, appear in interbedded shales containing thin coals; in sand wedges of littoral, or possibly shoal, origin; or if in impure limestones, as in West Virginia, at horizons of limestone breccias. In fact, the discovery of these plants is very important, as drawing attention to the occurrence of diastrophic movement during the long period of Mississippian marine sedimentation. The floras and sections have not yet been studied sufficiently to show how many uplifts took place in one region or another of the Appalachian trough during Mississippian time. According to the

writer's opinion, the examples cited not only point out movements which may subdivide Mississippian time, but they also lend support to the views of Ulrich as to the shallowness of the Mississippian seas.

In the abundant and familiar cases of the association of finely preserved leaves and fern fronds with marine shells in the roofs of coals in all the epochs of vascular land plant life, Paleozoic, Mesozoic, Cenozoic, and Recent, and in various regions of the world, the coals and their underlying old soils bear witness to their paleogeographic relations as coastal or lagoonal swamps which at the moment of molluscan invasion had just been inundated by the sea.¹¹

The deductions drawn from the occurrence and conditions of land plant material in the oceanic areas of today and from the stratigraphic relations and state of the corresponding fossils found in the older deposits, appear fully to justify the conclusion that the presence of clean and well preserved leaf material in limestones or other marine sediments constitutes satisfactory proof of proximity of the deposit to land; as, conversely, the occurrence of water-worn, partially decayed, incrustated, or corroded material permits the conclusion that the specimens may have been for some time in water and are therefore liable to have been transported for some distance. Unfortunately, the evidence of fossil plants, though of the highest value in paleogeographic deductions, is so rare as usually to be wanting on the occasions of greatest need.

*ARE THE FOSSILS OF THE DOLOMITES INDICATIVE OF SHALLOW, HIGHLY
SALINE AND WARM WATER SEAS? ¹*

BY STUART WELLER

It must be recognized at the outset, in the discussion of the subject which has been assigned me, that all dolomitic formations have not been deposited under like conditions. In such magnesian beds as are present in the Cayugan period of the Silurian, we find a most peculiar fauna, constituted almost wholly of the strange Eurypteroid arthropods whose fossil remains are almost never found in association with typical marine faunas, but which are present in situations, such, for instance, as the plant-bearing beds of the Pennsylvanian, which indicate that they must have lived in non-marine waters. The stratigraphic association of these Cayugan, Eurypterus-bearing beds with beds of salt and gypsum would

¹ Manuscript received by the Secretary of the Society May 23, 1911.

¹¹ The plant-bearing limestones of the Purbeck on the Dorset coast lie on the dirt beds (old soils), on which the vegetation grew.

suggest at once that the waters of the period were highly saline and perhaps shallow; but, so far as I am aware, there is no inherent characteristic of the fossil *Eurypterus* which can in any way suggest that it may not have been a truly marine organism, and our conclusion that it was not such an organism is drawn from the physical surroundings of the fossil itself, rather than that the physical conditions are what we believe them to be on account of some peculiarity of the fossil.

I believe, however, that the dolomitic formations which it was intended that I should discuss are the far more widespread formations of Paleozoic time, such as the Niagaran and Galena formations of the Upper Mississippi Valley, and it is altogether permissible to assume that these formations were deposited under very different conditions than were the Waterlime beds of the Cayugan. In most dolomitic formations, such as those just mentioned, the fossils present are preserved in a very imperfect condition, almost always in the form of casts and moulds, and are often more or less obliterated, so that accurate specific identifications are frequently or commonly difficult or impossible, and this unsatisfactory condition of the fossils themselves must be kept in mind in connection with the comparisons of faunas to be made later. In nearly all cases the fossils of the calcareous beds are better preserved, more numerous, and more readily identifiable than those in the dolomites.

A comparison of fossil faunas preserved in dolomitic formations with faunas of similar age in calcareous beds, ought to show whether the life of these ancient seas was notably reacted upon by the conditions which have been responsible for the existence of our conspicuous dolomitic formations. A comparison of this sort has been attempted between the fauna of the dolomitic Galena formation of Illinois, Wisconsin, Iowa, and Minnesota and the fauna of the typical Trenton limestone of the east, two formations which are believed to be essentially contemporaneous. A census of the Galena fauna, in which it has been the purpose to exclude all forms except those which occur in the dolomitic facies of the formation, has been compiled. Perhaps the most characteristic member of the fauna is *Receptaculites*, several species of which genus are recorded, of which *R. oweni* is the most common. This genus is represented in the typical calcareous Trenton limestone of New Jersey and elsewhere in the East, and the most characteristic Galena species occurs in such great numbers in the upper portion of the calcareous Kimmswick limestone of southeastern Missouri that this formation was called the *Receptaculite* limestone by the early Missouri geologists. The corals are sparsely represented in the fauna, an undetermined species of *Streptelasma* being the

only form worthy of record, and this genus is one which is well represented in the calcareous limestone of the East. The Echinodermata are so unusual, and when present so poorly preserved, that they may be ignored in this place. The Bryozoa are represented by a few forms too poorly preserved for accurate determination, but the commonest form is probably *Prasopora*, a genus which is one of the most conspicuous in the calcareous Trenton elsewhere. The Brachiopoda have a goodly representation, the following genera being recorded: *Lingula*, *Platystrophia*, *Dalmanella*, *Dinorthis*, *Orthis*, *Rafinesquina*, *Plectambonites*, *Leptaena*, *Rhynchotrema*, and *Cyclospira*. All of these genera are present in abundance in calcareous formations of essentially the same age as the Galena, and there is no single species in the Galena which does not occur in these calcareous formations. The Pelecypoda are represented by nine genera, as follows: *Byssonychia*, *Clionychia*, *Orthodesma*, *Cyrtodonta*, *Vanuxemia*, *Ctenodonta*, and *Cuneamya*. As in the case of the Brachiopoda, all of these genera are typically represented in calcareous beds elsewhere, although one or two of the species recorded have been described exclusively from the Galena formation. The Gastropoda constitute the largest single element in the fauna, fifteen genera being recorded, as follows: *Bellerophon*, *Phanerotrema*, *Lophospira*, *Liospira*, *Clathrospira*, *Hormotoma*, *Cœlocaulis*, *Eccyliopterus*, *Helicotoma*, *Ecculiomphalus*, *Maclurea*, *Maclurina*, *Trochonema*, *Holopea*, and *Fusispira*. A small minority of the species of these Gastropoda have been described from the Galena, and are not as yet recognized elsewhere, but every one of the genera and most of the species are well represented in calcareous formations of similar age. The Cephalopoda are represented by the genera *Cameroceras*, *Orthoceras*, *Triptoceras*, *Oncoceras*, and *Cyrtoceras*, and, as in the case of the other groups of organisms mentioned, these, too, are well represented by the identical species in calcareous formations. Only one trilobite genus, *Illænus*, is recorded, but this genus, and even the same species, occurs in abundance in contemporaneous calcareous beds.

From the facts gleaned in such a census of the Galena faunas, there seems to be no evidence whatever for concluding that the life conditions in the Galena sea were in any respect different from those of the basins which are now represented by purely calcareous sediments. There is no single characteristic of the fauna which would suggest that the waters were more saline, warmer, or shallower than the seas in which, for instance, the Trenton limestone of the East or the Kimmswick limestone of southern Illinois and Missouri were deposited. It is ordinarily conceded that an intensification of the salinity of sea waters produces a

depauperation of the fauna, but the fauna of the Galena is notably composed of the larger and more robust forms, probably because the smaller and more delicate shells have been obliterated by secondary chemical changes in the sediments.

A study of the fauna of the dolomitic Silurian formations of northern Illinois and southern Wisconsin, in connection with the faunas of contemporaneous non-magnesian formations elsewhere, affords another opportunity for similar comparison. In this fauna there are recorded fifty or more species of corals distributed among some twenty genera. All of these genera and many of the species occur elsewhere in non-magnesian formations, many of them in the Ohio Valley. Among the Crinoidea seventy or more species are known, belonging to nearly thirty genera. Most of these genera and many of the species are well represented elsewhere in America in non-magnesian formations of essentially the same age, and other genera, not known outside this dolomitic formation in America, are known from non-magnesian formations in northern Europe. The Cystoidea, Brachiopoda, Mollusca, and Trilobita all tell the same story as the Corals and the Crinoids. All these groups are represented in the fauna by many genera and species; the genera are in almost all cases well represented in non-magnesian formations, and a large majority of the species also are common elsewhere. From the consideration of this fauna it seems impossible to postulate that the sea in which it lived was any more saline, shallower, or warmer than the contemporaneous seas whose life is now preserved in non-magnesian formations, either calcareous or argillaceous.

It is only in the Guelph formation of the Silurian and in its equivalents that we may perhaps detect a faunal element indicative of greater salinity, in the association of the more or less diminutive and delicate-shelled species with the large and thick-shelled brachiopods, *Trimerella*, *Monomerella*, and *Rhinobolus*, and the similarly thick-shelled pelecypods, *Megalomus* and *Goniophora*. The suggestion that this assemblage of forms in association with the abundance of reef-building corals indicates a more than normally saline sea has been made by Clarke and Ruedemann, and I am not ready to dispute the truth of their conclusion, but it must be recognized that this same fauna occurs in non-magnesian sediments in the higher beds of the Gotland limestone of Sweden.

Other widespread dolomitic formations in the American Paleozoics do not lend themselves so readily to the solution of the problem in hand. The widely distributed dolomitic formations of late Cambrian and early Ordovician age are in general rarely fossiliferous, so that their known

faunas are altogether too meager to permit their being used as a basis for any conclusion in the matter. In the case of certain Devonian dolomitic formations—as, for instance, the Middle Devonian beds at Milwaukee, Wisconsin, and the dolomitic beds which are present in the Devonian section of Iowa—we have faunas constituted of species which, almost without exception, occur elsewhere in calcareous sediments. The same is true of certain Ordovician formations other than the Galena.

In conclusion it may be stated that from the evidence of the fossils alone there seems to be no reason for assuming that our widespread dolomitic formations of Paleozoic age have been deposited under conditions which are notably different, as regards salinity, temperature, or depth, from those under which non-magnesian formations, either argillaceous or calcareous, have been laid down. Chemical geologists are almost unanimously agreed that in general the dolomitization of limestone is a secondary process, and the paleontological evidence, so far as it is available, seems to substantiate that view. Formations now dolomite were in all probability originally deposited as limestones, and have been altered to dolomites since their original deposition, while other beds entirely similar in original condition have not been modified, but persist to the present time as true limestones.

*STRATIGRAPHIC SIGNIFICANCE OF THE WIDE DISTRIBUTION OF
GRAPTOLITES¹*

BY RUDOLF RUEDEMANN

I have been asked by your President to speak on the stratigraphic significance of the wide distribution of graptolites.

This title assumes the wide distribution of the graptolites as an established fact. It is such, but with a certain qualification that will be considered later.

The closer investigation of the graptolites in Europe, America, and in Australia has brought out the fact of the presence in all three continents of the common or guide graptolites, of the Ordovician, at least, and of the general agreement of the sequence of the zones. The distribution of an important fraction (roughly, at least one-third) is world-wide.

The structure of the graptolites has shown that the earlier forms without axes (*Axonolipa*) were for the greatest part pseudoplanktonic—that is, they drifted about fastened to seaweed—while the later *Axonophora* were planktonic or floated by means of apparatus of their own.

¹ Manuscript received by the Secretary of the Society May 23, 1911.

The combined facts of the world-wide distribution of the more common graptolites and of their planktonic mode of life, together with the restriction of the graptolites to either the edges of continents or former deep submarginal troughs, lead to the conclusion that the home of the graptolites was in the practically permanent oceanic basins, and that they were but strangers in the relatively occasional epicontinental seas.

This conceded, it further follows that these oceans were connected, and that the graptolite horizons of world-wide distribution indicate synchrony and not merely homotaxy, and thus are probable means of world-wide correlation; further, that where the graptolites are found in a series of zones they indicate near-oceanic conditions—that is, proximity to an ocean—the presence of oceanic currents, which carried these planktonic organisms through the basin, and possibly, also, a greater depth of water than usually occupied continental basins and troughs.

Each of these conclusions requires, again, some qualification and explanation.

First, although a certain percentage of the species in every zone may be world-wide, others differ sufficiently to warrant the recognition of provincial features also among the graptolites. The minor provincial differences correspond apparently to the opposite sides of oceanic basins, the larger ones to the different oceans themselves. It follows from this that where the latter differences are pronounced, as in part of Ordovician time, that the oceans must on one hand have been in sufficient intercommunication to permit world-wide distribution of the common graptolites by the currents, and still sufficiently defined and separated to also favor the development of provincial characters in the plankton, or, in other words, the relative areas of water and land were not materially different from the present condition.

The inference that the graptolites were but strangers in the epicontinental seas explains the observation that they occur there only sporadically—as, for instance, the zone of *Monograptus clintonensis* and *Retiograptus venosus*, in the upper Williamson shale of the Clinton of western New York. Where graptolite faunules appear as abruptly and for such a brief period only, as in the Williamson, it is safe to say that this incursion is caused by the breaking of an ocean current through a barrier, and its free, though short-lived, passage through the basin. In the case of the Williamson shale I am convinced that the eastern embayment of the Mississippi basin, mapped by Professor Schuchert for the Wolcott-Williamson stage, connected at this brief stage with the Appalachian basin,

thereby allowing a current to enter from the east and bring in the multitude of graptolites. It agrees with this conclusion that the graptolite horizon of the Williamson continues farthest east of all the Clinton beds recognized in western New York. A similar invasion of graptolites, to which we shall recur later, from the east as far west as Cincinnati had already taken place in Utica time.

Where the graptolites occur in a longer series of beds, they indicate a trough or basin near an ocean. In the memoir on North American graptolites I have pointed out the remarkable continuity of the formation of graptoliticiferous beds in certain regions as indicating that deposition in such areas was more nearly continuous than seems to have been the case in most other areas of fossiliferous rocks, or, in other words, that the conditions producing the deposition of graptolite shales tended to persist for a long time in the same region. From this it is inferred that long series of graptolite zones indicate the former existence of long persisting deep troughs in the places where these series are now found. In most, if not all, cases these troughs correspond to the sites of Paleozoic geosynclines.

But even where the deposition of graptolite beds was apparently continuous for a long time, as in our Levis basin, the successive horizons are not connected by transitional beds, but marked by the rather abrupt appearance of new forms. This means that either our knowledge is still imperfect and the connecting subzones have not yet been discovered—which is certainly true in some cases—or that many of them do not exist in these basins. Localities like the Deep Kill, where several zones could be followed bed for bed, would suggest that such transitional zones are missing there. This fact, coupled with the planktonic mode of life of the graptolites, indicates that this uninterrupted development has to be sought in the oceanic basins, and that the horizons seen in the graptolite beds are for a large part but snapshots at intervals out of this continuous development in the oceans. The non-graptoliticiferous intervals mark not only the temporary absence of currents sweeping in from the ocean and carrying the graptolites through the channel, but they probably also cover intervals of non-deposition.*

Since the Axonolipa were fastened to seaweeds and the Axonophora floated free (but judging from the relative stiffness of their axes, prob-

* At least Doctor Ulrich, who has given me the benefit of his extensive observations in this problem with his well known liberality, writes me that he has stratigraphic evidence that deposition in these submarginal basins was as much interrupted as that in the more inland basins.

ably outside the reach of the waves and in moderate depths of the sea), and both were dependent on oceanic currents for transportation, it is thought impossible that they could have entered culs-de-sac such as the Baltic Sea in any considerable quantities, and their abundant and continued presence is taken as indicating the deposition of the beds in either the ocean or a sea with free egress and ingress.

Scattered occurrences of graptolites may occur in epicontinental seas by the slow action of an entering surface current in a tropical hypersaline sea, such as the Red Sea of today, or through an entering bottom current in a brackish sea, as the Baltic Sea now is.

The black carbonaceous graptolite shales do not indicate conditions of a nearly inclosed basin, such as is now exemplified by the Black Sea, for in the latter life exists only near the surface, and the *Axonophora*, at least, quite surely lived in the more quiet depths, nor would in such a basin be found the great mass of floating seaweed to support the *Axonolipa*. Many different graptolite zones occur, as a rule, in a small thickness of rock, but sometimes they are also embedded in coarser sediments. The most essential requisite for the formation of the black fine grained graptolite shales is, therefore, not the depth, but the tranquillity of the water. The graptolite shales, therefore, indicate a zone between the agitated water, where coarser sediments are deposited, and the dead or currentless water of the deeper sea. Their longitudinal distribution, then, also indicates the direction of a coastline, which has to be sought on the farther side of a parallel band of coarser littoral sediments, and two such flanking littoral bands may be looked for in narrow channels like the Levis Channel.

The last corollary from the world-wide oceanic distribution of the index graptolites is that their zones are not homotaxial, but virtually synchronous, these graptolites thus being index fossils for absolute time correlation. This conclusion postulates that the new graptolite species either developed in all oceans *pari passu*, or that if new forms originated in one oceanic basin they so rapidly spread into the others that deposition of rock did not take place sufficiently quick to record this migration in the rocks. The former hypothesis of the uniform development of the index graptolites in all oceans would presuppose the absence of any physical differences in the oceans, and it fails to account for the provincial forms; the latter hypothesis, of the immediate diffusion of new forms, is apparently not quite supported by all the facts, for some of the common graptolites do actually appear later in one basin than in another. It is thus claimed, to cite one instance, by T. S. Hall that in *Australia* *Loganograptus logani* appears much later in the graptolite horizons than

in Europe, and we may add that we have found the same late appearance in the Deep Kill beds of New York. It is hence apparent that these graptolites actually traveled from one basin to another, and with different rate perhaps through their position in different depths. The great majority of the world-wide species, however, appeared together. If these at all traveled with the ocean currents they must have, after once entering these currents, been diffused in a, geologically speaking, immeasurably short time or have appeared synchronously. In that case the identical graptolite horizons are the surest means of intercontinental correlation.

We will now briefly consider the principal cases of wide distribution of graptolites.

The zone of *Dictyonema flabelliforme*, which in Europe characterizes the boundary between the Cambrian and Ordovician, is known as yet from the Atlantic basin only, and its occurrence in the base of the graptolite zones of the Levis Channel would indicate early Atlantic connections. This horizon in Europe was first made the top of the Cambrian, and lately the bottom of the Ordovician, and it has been also assigned in America to the top of the first or bottom of the second system by several authors.*

The Beekmantown zones, as represented by the Deep Kill shales of New York, are essentially Atlantic in their composition, but with some undoubted Pacific elements, indicative of some connection with the Pacific at times. The occurrence of these Beekmantown graptolites in Arkansas and Nevada would seem to suggest a transcontinental connection with the Pacific. The principal Atlantic graptolites are fully at home in the Pacific. We find, for instance, one horizon in Victoria, Australia, characterized by *Didymograptus bifidus*, *D. extensus* (?), *Tetragraptus quadrirachiatulus*, *T. serra*, *T. fruticosus*, *Dichograptus*, *Phyllograptus typus*, and *P. sp.* And the fact that the differences in the time of appearance of some important forms between Australia and Europe (as the later appearance of *Loganograptus logani* and earlier appearance of *Didymograptus bifidus* in Australia) are exactly duplicated in our Deep Kill zones, and the presence of *Gonograptus thureaui* in both Australia and the Levis Channel are strong arguments not only in favor of some connection of the Levis basin with the Pacific Ocean, but even of

* Doctor Ulrich writes me regarding the age of this horizon: "The *Dictyonema flabelliforme* and the main *Tetragraptus* zones I regard as in large part if not entirely older than the lower part of the 4,200 feet of Canadian (Beekmantown) limestones in central Pennsylvania. This is indicated by the facts (1) that mutations of *Didymograptus bifidus*, *D. amplius*, and *Phyllograptus ilicifolius* occur in northern Arkansas only in lower Canadian deposits, and (2) that the conglomerates at Quebec contain late middle or upper Ozarkian trilobites."

the arrival of some of the forms of this far distant basin by a current from the west.

The writer has inclined to the view that this connection with the Pacific could have been transcontinental by means of the Beekmantown transgression. Doctor Ulrich, however, has arrived at a different view, "since the continental seas of the required size and location can not be established and indeed seem to have been impossible." He states in a letter to me his conception as follows:

"As I see it, the widely distributed graptolite faunas, like the *Tetragnostus* and *Nemagnostus*, attained their great dispersal solely by means of oceanic currents. The channels in whose deposits we now find these faunas were, as you yourself have indicated, thoroughfares for such currents. In the cases of the Levis, Athens, and Ouachita troughs, it seems to me demonstrable that they were channels connecting at both ends with Atlantic oceanic basins and that they passed around the inner sides (and thus separated off from the main mass of the continent) certain large marginal islands (Taconia, Appalachia, and Llano). As plotted on my maps, the Levis Channel passes up the Saint Lawrence to the east side of the Champlain Valley, and thence south to northern New Jersey, where it joins the Atlantic. The Athens Channel begins on the north at Chesapeake Bay, extends along the eastern side of the Appalachian Valley to central Alabama, beyond which it connects with the Gulf of Mexico. The Ouachita Channel connected with the Gulf through the Mississippi embayment, passed westward through central Arkansas and Oklahoma, and thence probably turned southward to open into some western part of the Gulf.

"How these graptolites got into the Pacific, or how those of the Pacific got into the Atlantic is a more difficult problem. Possibly the isthmian region was submerged at such times—or it may be that a channel across northwestern South America afforded the necessary means for communication. We do not know."

The graptolite fauna of the Normanskill shale, of approximate Black River age, is distinctly Atlantic in its aspect and is common to north-eastern America and Europe. But some of its elements have also found their way into Arkansas and British Columbia and into the Pacific basin and Australia.

The leading species of the graptolite shales corresponding to the Upper Trenton (Magog shale) and of the Utica shale are again common to Europe and eastern North America and are Atlantic forms. In Utica time an arm of the Atlantic entered from the northeast, or Lower Saint Lawrence region, far on the continental platform, and, as indicated by the graptolite facies, had one or more outlets that completed a circuit back to the Atlantic, the current entering from the Saint Lawrence re-

gion, according to evidence found by the writer, in the prevailing direction of fossils in the Mohawk region. A few of our Utica forms, as *Diplograptus quadrimucronatus*, *Dicranograptus nicholsoni*, again have reached the Pacific basin, but not by way of a North American epicontinental sea.

The absence of typical graptolite shales in the Frankfort and Lorraine suggest that then the arms of the sea that spread over the continent, at this time from the south, were ending blind toward the northeast.

The Siluric, aside from small occurrences on our northeastern Atlantic border, has furnished only two occurrences of graptolites in the Williamson shale of the Clinton and a later one in the Niagaran of eastern Missouri. Since only the Upper Siluric graptolite faunas of the Atlantic basin are as yet known, no evidence as to the possible relationship of these faunules to other than the Atlantic basin is at hand.

In conclusion, I wish to emphasize the fact that inasmuch as the graptolites as planktonic organisms were able to cross the oceans and seas directly instead of creeping along the shores, as the littoral benthonic faunas did, they must not only have wandered infinitely faster and farther, but may even have gone in opposite directions to the coexistent littoral faunas. While the appearance of the latter proves the establishment of a bridge or littoral highway, that of the former often indicates the opening of an oceanic highway with currents as carriers for the graptolite fauna. And while the former, as a rule, are separated by the deep sea, the latter are connected by it.

PHYSICAL CONDITIONS UNDER WHICH PALEOZOIC CORAL REEFS WERE FORMED¹

BY THOMAS WAYLAND VAUGHAN

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DEFINITION AND ORIGIN OF CORAL REEF

A coral reef is a ridge or mound of limestone, the upper surface of which lies, or lay at the time of its formation, near the level of the sea, and is predominantly composed of calcium carbonate secreted by organisms, of which the most important are corals. A coral reef is, therefore,

¹ Manuscript received by the Secretary of the Society May 28, 1911.

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primarily a limestone formed through the activity of organisms secreting carbonate of lime.

Since the physical conditions prevalent during the formation of fossil coral reefs can not be ascertained by direct observation, it is necessary to resort to the process of deduction. Evidence for establishing criteria may be derived from two sources: The first, through the study of the conditions under which modern reefs are formed, and the determination of the factors necessary for the physiologic activity to which large accumulations of calcium carbonate are due; the second, through the investigation of the physical character and the nature of the bedding or stratification of the sediments in which the fossil reefs are embedded. An attempt will be made to derive criteria from both these sources and to apply them in the elucidation of the problem.

RECENT CORAL REEFS

COMPOSITION

A modern coral reef is not entirely composed of the skeletons of corals, the remains of nullipores, mollusks, echinoids, and littoral foraminifera forming important constituents. Reef corals do not exclusively belong to the Madreporia, the Alcyonaria and Hydrozoa both contributing a certain quota of material. In the succeeding remarks the distribution of these groups of organisms with reference to depth and intensity of light, temperature, motion of the water, character of bottom, composition of the oceanic salts, and specific gravity of the water will be considered.

DEPTH OF WATER AND INTENSITY OF LIGHT

The literature on the maximum depth at which reef-building Madreporaria may grow vigorously is extensive, and there is practical unanimity among all investigators that 25 fathoms is the greatest depth at which they work effectively, although an occasional reef species may extend downward to a depth of 40 fathoms. The most luxuriant growth, however, is in shallower water, from just below low tide level to perhaps 10 or 15 fathoms. These bathymetric limits of the Madreporaria usually apply to the Alcyonarian *Heliopora* and *Tubipora*, the Hydroid *Millepora*, and the Nullipores, although *Heliopora* and *Millepora* in the Maldives are important constructional agents to depths between 35 and 40 fathoms, and Nullipores extend to a depth of 35 fathoms.²

Several factors besides pressure are correlated with increasing depth. One is the intensity of light. In this connection the following remarks

² J. Stanley Gardiner: Fauna and geography of the Maldiva and Laccadive archipelagoes, pp. 342-326.

are quoted from Prof. Johan Hjort's article on "The *Michael Sars* North Atlantic Deep-Sea Expedition:"³

. . . "Now, if we calculate the depth to which the rays of the sun penetrate, after passing through the same distance in the water, assuming always that the rays are direct, and that the rate of absorption is the same, we find that the rays will have passed through the same distance to reach a depth of 500 meters in 50 degrees north latitude that they will pass through to reach 650 meters in 33 degrees north latitude, or 300 meters in 67 degrees north latitude.

"However, the transparency of the water varies greatly in different regions. If we take the results of previous observations during different expeditions, we may set down the visible depth in the open sea as being, roughly, 50 meters in 33 degrees north latitude, 40 meters in 50 degrees north latitude, and 25 meters at the outside in the Norwegian Sea in 67 degrees north latitude. Taking this into consideration, we find that there will be the same *intensity* from the rectilinear rays—

"In 33 degrees north latitude, at about 800 meters' depth.

"In 50 degrees north latitude, at about 500 meters' depth.

"In 67 degrees north latitude, at about 200 meters' depth."

"During the Atlantic cruise of the *Michael Sars* we undertook a series of measurements of the intensity of light with a photometer constructed by Dr. Helland-Hansen; to determine the intensity of the different color rays, Dr. Helland-Hansen made use of panchromatic plates and gelatine color-filters. The observation south and west of the Azores (that is to say, at the southern stations) showed that the rays of light strongly affected the plate at a depth of 100 meters. The red rays were weakest here, while the blue and ultra-violet rays were strongest. At a depth of 500 meters the blue and ultra-violet rays were still distinctly visible, and at a depth of 1,000 meters the ultra-violet rays were yet perceptible. In 1,700 meters, however, there was not the faintest trace of light, even after the plates had been exposed for two hours in broad daylight."

A natural experiment at the Tortugas shows the effect of light on the habitat of shallow-water species. The government wharf at Fort Jefferson is supported by iron piles coated with cement. On all the peripheral piles (on both ends and on both the landward and seaward sides of the wharf) there are many corals, while those in the permanently shaded area bear none at all. Species of reef corals placed in a light-proof live-car die after the light has been excluded for several weeks. Strong light is one of the essentials for the life of recent species of reef corals.⁴

³ This quotation is from a proof copy kindly loaned by Sir John Murray. The article, a lecture before the Royal Geographical Society, appears in the *Geographical Journal*, 1911; but as I have not, on June 22, seen the issue of the *Magazine* containing it, I can not give the page reference.

⁴ The presence of commensal algae (*Zoanthoxellæ*) is here noted, but a discussion of them and their functions would be too great a diversion.

Decrease in temperature with increase of depth in the ocean is well known.

TEMPERATURE

Dana long ago showed the minimum temperature of the year to be a critical factor in determining the possibility of reef corals living in a locality where conditions were otherwise favorable for their growth, and designated 68 degrees Fahrenheit as the lowest temperature these organisms could stand. The mean annual temperature of the water must be above 70 degrees Fahrenheit. Therefore a high temperature is necessary for the vigorous growth of reef-building corals.

The importance of high temperature for the secretion of carbonate of lime in quantity by marine organisms can best be presented by giving the words of Sir John Murray:⁵

"During the past year or two I have carefully collected all the available temperatures of the surface waters of the ocean, and from these have constructed a map showing the annual range of temperature in different regions of the ocean. This map shows that the surface of the sea may be grouped into five great zones, namely: (1) A nearly continuous equatorial zone, where the temperature is high and the range throughout the year does not exceed 10 degrees Fahrenheit. This zone includes all the principal coral-reef regions. (2 and 3) Two polar zones, where the temperature is low and the annual range likewise does not exceed 10 degrees Fahrenheit. In these zones there are relatively few lime-secreting organisms. (4 and 5) Two regions lying between the equatorial zone and the two polar zones, where a wide range of temperature occurs between the different seasons (the annual range amounting to as much as 52 degrees Fahrenheit in some places). In these temperate regions the secretion of carbonate of lime appears to be much more active in the warmer than in the colder months. It thus appears that the most favorable conditions for lime-secreting organisms are met with in the warm, equable tropical waters of the ocean, and here, as a matter of fact, we find the greatest development of corals and the largest number of lime-secreting pelagic organisms. In the polar areas and in the cold water of the deep sea there is, as is well known, a feeble development of all carbonate of lime structures in marine organisms.

"From experiments which have been carried out by Mr. Irvine and myself at the Granton Marine Station we have reason to believe that this distribution is dependent primarily on the physical or temperature conditions of the oceanic waters. When carbonate of lime is precipitated by alkaline solutions, such as carbonate of soda, carbonate of ammonia, or carbonate of methylamine, the effect of temperature is very marked, and it appears to be the case that the secretion of carbonate of lime by organisms is of the nature of a fine precipitation in the interior of the soft structures.⁶ If we add sufficient carbonate of ammonia to sea water at different temperatures to convert all the

⁵ Natural Science, vol. II, 1897, pp. 25-27.

⁶ Murray and Irvine: Proc. Roy. Soc. Edin., vol. xvii, 1890, pp. 79-109.

lime salts present into carbonate, we obtain a precipitate which varies both in its crystalline form, in amount, and in time of formation. At 32 degrees Fahrenheit the precipitate begins to form in about six hours as small but distinct crystals of calcite, the quantity in twenty hours amounting only to 0.2 gramme from a litre of water. At a temperature of about 47 degrees Fahrenheit a mixture of calcite and aragonite is precipitated; at 80 degrees to 90 degrees Fahrenheit the quantity precipitated is about 0.6 gramme; the precipitate begins to form in from a half to one hour, and it appears to consist of minute crystals of aragonite. It thus seems evident that carbonate of lime would be more easily and more rapidly secreted in the high temperatures of the tropics by means of the effete products of the organism."

MOTION OF THE WATER

The adaptations of shallow-water corals to their respective habitats are various. Although this subject has received more or less attention since the days of Darwin, there is still some divergence of opinion. Areas swept by strong, continuous currents are not favorable for the growth of corals, as the free-swimming planulæ have no opportunity to affix themselves. Some species grow best where they are protected from the ocean breakers; others thrive best in the region of the breakers or just below the level of their pounding. For vigorous growth, the water needs to be agitated and changed—that is, there must be circulation that will continually supply fresh water.

CHARACTER OF BOTTOM

The bottom must be firm or must be overlain by masses of rock, so as to supply suitable conditions for the attachment of settling coral larvæ, and the waters must be relatively free from silt, as deposits of such material will bury the young corals and in considerable quantities will smother older specimens.

COMPOSITION OF THE OCEANIC SALTS

There is no noticeable difference in the composition of the oceanic salts in coral-reef regions from that in other regions of the ocean. The following data are taken from F. W. Clarke's "The data of geochemistry," pages 94-95:

*Mean of Seventy-seven Analyses of Ocean Water from many Localities,
collected by the Challenger Expedition*

W. Dittmar, analyst. *Challenger Report, Physics and Chemistry, vol. 1, 1884,*
p. 203. Salinity, 3.301 to 3.737 per cent.

Cl	55.292
Br188
SO ₄	7.692
CO ₂207

Na	30.593
K	1.106
Rb
Ca	1.197
Mg	3.725
Fe, SiO ₂ , PO ₄
Fe, NH ₄ , NO ₃
Al ₂ O ₃ , Fe ₂ O ₃ , SiO ₂
<hr/>	
	100.000

" . . . allowing for all possible sources of divergence, the essential uniformity in composition of ocean salts is perfectly clear. The mass of the ocean is so great, and the commingling of its waters by winds and currents is so thorough, that the local changes produced by the influx of rivers are exceedingly small. The salinity may range from less than 1 to over 4 per cent, but the saline composition remains practically the same."

SPECIFIC GRAVITY OF THE WATER

The following data have been compiled from the *Challenger* reports:

Localities.	Range in specific gravity at 15° 56 C.
<i>Atlantic Ocean:</i>	
Bermuda to Azores.....	1.02686 to 1.02715
Cape Verde Islands to Saint Paul Rocks.....	1.02589 to 1.02706
Saint Paul Rocks to Fernando Noronha.....	1.02667 to 1.02699
Fernando Noronha to Bahla.....	1.02628 to 1.02748
<i>Pacific Ocean:</i>	
Tongatabu to Fiji Islands.....	1.02640 to 1.02659
Fiji Islands to Cape York, Australia.....	1.02609 to 1.02672
Meangis Islands to Admiralty Islands.....	1.02405 to 1.02576
Meangis Islands to Japan.....	1.02564 to 1.02570
Admiralty Islands to Japan.....	1.02571 to 1.02580
Sandwich Islands to Tahiti.....	1.02587 to 1.02696
Tahiti to Valparaiso.....	1.02714 to 1.02519

The total range is from 1.02405 to 1.02748, or .003.

To summarize the data on conditions under which modern coral reefs are formed: (a) *depth*, maximum, 25 fathoms, light strong; (b) *temperature*, annual minimum, 68 degrees Fahrenheit; annual mean, above 70 degrees Fahrenheit; (c) *water*, agitated and circulating; (d) *bottom*, firm or rocky, without silty deposits; (e) *composition of the oceanic salts*, as for the oceanic waters as a whole; (f) *specific gravity*, as for the ocean in general, range 1.02405 to 1.02748. Of these conditions shallow water, strong light, high temperature, circulating water, a comparatively clean sea-floor, and a chemical composition of the water insuring a supply of calcium salts for the formation of the skeletons are essential.

PALEOZOIC CORAL REEFS¹

IN GENERAL

The following sketch of Paleozoic reefs is very general, and is intended merely to indicate their wide stratigraphic and geographic distribution, at the same time mentioning a few of the more abundant types and facies of reef-forming organisms.

CAMBRIAN

North America.—In the lower Cambrian the *Archæocyathina* form banks of reef-like character in Newfoundland, California, and Nevada. There are, in a zone comprising a part of the upper Cambrian and the lower part of the Calciferous in New York, Pennsylvania, Virginia, Tennessee, Missouri, Wyoming, and Alaska, reefs predominantly composed of *Cryptozoon*.

Other lands.—Outside of North America the *Archæocyathina* are found in Sardinia, Spain, northern Scotland, northern Siberia, and Australia.

ORDOVICIAN

North America.—Reefs of *Cryptozoon minnesotensis* occur in the lower part of the Canadian group, in Vermont, New York, Alabama, Arkansas, and Minnesota. In the Chazy group reefs are formed by *Stromatocerium* and *Stylaræa* in New York, Tennessee, Kentucky, and Oklahoma; in the Black River, by *Stromatocerium*, *Columnaria*, *Tetradium*, and *Halysites* in Canada, New York, along the Appalachian Valley to Alabama, in Kentucky, Tennessee, Missouri, Wisconsin, and Minnesota; in the Trenton group, by *Stromatocerium*, *Columnaria*, and *Tetradium* in Tennessee and Kentucky; in the Cincinnati, by *Stromatocerium*, *Columnaria*, and *Tetradium* in Tennessee and south central Kentucky. In the Richmond group there are reefs composed of *Stromatocerium*, *Columnaria*, *Tetradium*, *Beatricea*, *Labeckia*, *Calapæcia*, *Favosites*, *Halysites*, and *Heliolites* in Baffin Land, Anticosti, northern Michigan, Illinois, Indiana, Kentucky, Tennessee, Texas, Oklahoma, Arkansas, Missouri, Colorado, Nevada, Wyoming, and Alaska.

SILURIAN

North America.—In the Niagaran group reefs are formed by *Stromatopora*ids, *Favosites*, *Halysites*, *Heliolites*, *Lyellia*, *Zaphrentis*, and *Cyatho-*

¹ This account of Paleozoic coral reefs is based mostly on oral information received from Mr. E. O. Ulrich, Frech's "Ueber Korallenriffe und ihrem Anteil an dem Aufbau der Erdrinde," Himmel und Erde, Bd. 9, 1897, p. 97 et seq.; Zittel, *Traité de Pal.* t. 1; Geikie's "Text-book of geology;" Dana's "Manual of geology," and Grabau's "Paleozoic coral reefs," Bull. Geol. Soc. America, vol. 14, 1903, pp. 337-352.

phyllum in Wisconsin, Indiana, Ohio, Illinois, Kentucky, western Tennessee, Iowa, and British Columbia; in the Cayugan, reefs are locally formed by Stromatoporoids, *Favosites*, and *Halysites* in New York and in the Appalachian Valley in Pennsylvania, Maryland, Virginia, and Tennessee.

Europe.—Silurian reefs are reported in the Bala, upper Llandovery, and Wenlock groups of Great Britain, and in Norway, Gotland, the Baltic provinces of Russia, and Bohemia.

DEVONIAN

North America.—The Helderberg group contains reefs composed of Stromatoporoids, *Favosites*, *Halysites*, and a few *Rugosa* in New York, in the Appalachian Valley in Pennsylvania, Maryland, Virginia, West Virginia, eastern Tennessee, and Oklahoma; the Onondaga, reefs of Stromatoporoids, *Favosites*, *Michelinia*, *Cyathophyllum*, *Zaphrentis*, *Phillipsastræa*, *Acerularia*, *Cystiphyllum*, etcetera, at the southern end of Hudson Bay, in New York, Pennsylvania, Virginia, Indiana, Kentucky, and Minnesota; the Hamilton, reefs of Stromatoporoids, *Favosites*, *Michelinia*, and Cyathophylloids and other *Rugosa* in Ontario, New York, and Michigan. The upper Devonian reefs are composed of Stromatoporoids, *Michelinia*, and *Pachyphyllum* (the earlier rugose types of corals have become rare) in Iowa, Missouri, and Illinois.

Europe.—Devonian coral reefs are found in Devon, Boulogne sur Mer, Eifel, Ardennes, Belgium, Cologne, Elbingerode in the Harz, and the Karnish Alps.

CARBONIFEROUS

North America.—There are no known reefs, properly speaking, in the Mississippian. In the Tennessean, reefs composed of *Michelinia*, *Lonsdaleia*, *Lithostrotion*, *Zaphrentis*, etcetera, occur in Indiana, southern Illinois, Kentucky, Tennessee, and Alabama; in the Pennsylvanian, *Chætetes* and the rugose *Campophyllum* form reefs in the region from Texas to Kansas, and sporadically elsewhere.

Europe.—The carboniferous limestones of Ireland, Scotland, Belgium, and central Russia contain reefs composed of *Rugosa*, *Zaphrentis*, *Amplexus*, *Diphyphyllum*, *Clisiophyllum*, *Lithostrotion*, *Strephodes*, and *Columnaria*; also *Favosites*, *Syringopora*, and *Chætetes*.

A review of the reef-forming Cœlenterata of the Paleozoic formations shows that beginning with the Ozarkian group of the Cambrian the same large groups that are at present active reef-builders were then abundantly represented.

The *Archæocyathina* of the lower Cambrian were simple corals, and, although sufficiently abundant to form beds predominantly composed of

their remains, did not possess the massive facies of the typical reef-builders; it may, therefore, be unsafe to make from biologic data a deduction applying to them. But some information is furnished by the nature of the sediments in which they are embedded. Walcott^a gives the following localities for the species: Silver Peak, Nevada; Straits of Belle Isle, Labrador, and conglomerate limestone east of Troy and Schoolhouse No. 8, Washington County, New York. In the Silver Peak section the *Archæocyathinae* occur in a limestone and silico-argillaceous shale in association with *Olenellus gilberti*; in the Straits of Belle Isle, in gray, reddish, and greenish limestones, there occur the characteristic coral-reef limestones varying in thickness from 25 to 50 feet; east of Troy, New York, in a brecciated limestone showing evidences of wear in most instances. Walcott says:

"The arenaceous beds (with ripple marks and trails) of the western Nevada-California area and the interformational conglomerates of eastern New York proves the presence in both areas of relatively shallow water."

We can therefore safely say that some *Archæocyathinae* lived in shoal water, and, as they formed considerable accumulations of calcium carbonate, they probably lived in a warm sea. Regarding the oceanic temperature of the Lower Cambrian, Walcott says, in the article already cited:

"That more or less uniform and favorable, even warm, climatic conditions must be appealed to in explanation of the widespread occurrence of almost identical coral-like organisms in the Lower Cambrian and of the vast number of individuals of various species of trilobites, etcetera, in Middle Cambrian time."

In the Upper Cambrian the Stromatoporoid *Cryptozoon* obtained a great development, and continued into the basal Ordovician. This Hydrozoan formed spherical masses from 1 to 2 feet in diameter, or formed greatly expanded plates a foot or more thick and from 5 to 100 feet in horizontal extent.

The Rugosa are represented in the Middle Ordovician by *Columnaria*; the Alcyonaria, represented by *Halysites*, *Heliolites*, etcetera, soon appear, and the great coral reef-builders of Paleozoic time were initiated. These reefs are formed by the Hydroids, *Stromatocerium*, *Stromatopora*, *Beatricia*, *Labechia*, etcetera; the Alcyonarian, *Halysites*, *Heliopora*, etcetera; *Favosites* and its allies; a great profusion of Rugosa, including many genera of massive facies, as *Columnaria*, *Eridophyllum*, *Cya-*

^a Tenth Ann. Rept. U. S. Geol. Survey, 1890; Bull. U. S. Geol. Survey, No. 30, 1896.

^b Outlines of geologic history, with especial reference to North America. Symposium organized by Bailey Willis, p. 85.

thophyllum, *Stauria*, *Acervularia*, *Phillipsastræa*, *Strombodes*, *Pachyphyllum*, etcetera, and genera usually simple, but often with large individuals, as *Zaphrentis*, *Streptelasma*, *Amplexus*, *Blothrophyllum*, *Cystiphyllum*, *Heliophyllum*, etcetera, and *Chætetes*.

On the reefs of the present day the Hydroids are represented by *Millepora*; the Alcyonaria by *Heliopora* and *Tubipora*, and the Madreporaria by the composite group of coral designated the Hexacoralla. The same groups of reef-building organisms are represented in both the Paleozoic and Recent seas; in both they have the same facies as regards growth-form; in both their physiologic activity has resulted in the secretion of large quantities of carbonate from the surrounding sea-water, and in both submarine banks, known as coral reefs, have resulted. The general similarity of the organisms and the similarity in the result of their physiologic activity assuredly suggest similarity of conditions under which the physiologic process took place.

Certain Paleozoic reefs have been described in sufficient detail to give additional information on the conditions under which they were formed. Regarding the Silurian reefs of Gotland, we know that "on the flanks of the reefs are found conglomerates and breccias of coral masses, such as *Halysites* and *Cystiphyllum*, and crinoidal remains."¹⁰ The matrix of the Silurian reef exposed in Anschütz' quarry, Cedarburg, Wisconsin, "has the structure of a sandstone, by which name it is familiarly known."

Grabau furnishes the following information on the Devonian reefs of Wisconsin and New York:

"The reefs in the vicinity of Alpena [Michigan] are best exposed in the quarries opened in the Alpena limestone, which has a thickness of about 35 feet and is the middle member of the Hamilton or Traverse group in the Thunder Bay region. Reefs occur in higher and, to some extent, in lower strata of the group, but none of these are well exposed.

"In outline the reef is roughly dome-shaped, with slopes sometimes as great as 30 or 40 degrees. The height of the dome is equal to the thickness of the limestone stratum—about 35 feet in this region—and the greatest diameter, which is near the base, is perhaps several hundred feet. The chief reef-builders represented are *Favosites*, *Acervularia*, and *Stromatopora*, which form the main mass of the reef, while between them are found the smaller corals and bryozoa, as well as brachiopods, crinoids, and a few other types of organisms. There is an absence of stratification in the central reef mass, the structure being exceedingly irregular. Between the corals and shells is found a filling of coral sand, which generally consists of rather coarse fragments with a predominance of crinoid joints. Solution and recrystallization have not infrequently taken place, with the result that dog-tooth spar is of common occurrence.

"The coral heads are generally of large size; sometimes they are over-

¹⁰ Grabau: Bull. Geol. Soc. America, vol. 14, p. 848.

turned, but most of them appear to lie in their normal position of growth. In some places the crystalline coral sand forms most of the reef exposed, the large coral heads being scattered through the sand. The sand shows no stratification, so far as observed. The sand filling the cavities of the reef is generally much coarser than that forming the normal sediments on its flanks. In places at some distance from the center of the reef the rock consists of a breccia made up of brachiopods, bryozoa, and the small branching corals, with a plentiful interspersing of the joints of crinoid stems."

Concerning the reefs of the Traverse Bay region of Wisconsin, Grabau says:

"At intervals the section passes near enough to the reef to show the presence of numerous coral fragments. The fragments are all much worn and broken, and are embedded as boulders or pebbles in the stratified lime sands. Where they are abundant they constitute a veritable coral conglomerate (*calcirudite*), such as may be found near the borders of modern reefs. Good exposures of such conglomeratic beds are found in the quarries and shore sections east of Petoskey, where these coral pebbles (chiefly *Acervularia* and *Favosites* and the hydrocoralline *Stromatopora*) give the rock a strikingly mottled appearance. Not infrequently seams of carbonaceous material separate some of the layers of limestone, and in these plant remains are not uncommon. Within the thicker beds themselves the phenomena of contemporaneous erosion, of the wedging out of strata, and, occasionally, of cross-bedding and ripple marks, are met with. Indeed, all the phenomena seen in heavy bedded sandstones are found in these fragmental deposits."

He says, in describing the Onondaga reef of Williamsville, New York:

"The corals of the bedded limestone in the neighborhood of the reef are fragmental and may lie in almost any position. They indicate considerable wave activity around the margins of the reef."

By applying the criteria derived from the study of the conditions under which Cœlenterates may live and secrete calcium carbonate, and from the investigation of the physical characters, the bedding, and stratification of the sediments in which the coral reefs are embedded, the conclusions seem to follow:

DEPTH OF WATER AND INTENSITY OF LIGHT

An examination of the modern reef-forming corals has shown that they are effective workers only in depths less than 25 fathoms. Because of the zoologic affinity of the organisms, their similarity in growth-form, and the similarity of the result of their physiological activity, the conclusion appears justified that the reef-forming Cœlenterates of Paleozoic time lived in a depth of water similar to that in which those of Recent time live, or the Paleozoic reefs were formed in water not over 25 fathoms in depth.

An examination of the matrix in which the Paleozoic reef-forming corals are embedded gives information from another source bearing on the depth at which they grew. In the accounts of the Silurian reefs of Gotland, it is stated that "on the flanks of the reefs are found conglomerates and breccias of coral masses." The matrix of the Silurian reef exposed in Anschütz' quarry, Cedarburg, Wisconsin, has the structure of a sandstone. The spaces between the coral heads of the Devonian reef in the vicinity of Alpena, Michigan, "are filled with coral sand, which generally consists of rather coarse fragments with a predominance of crinoid joints. The sand filling the cavities of the reef is generally much coarser than that forming the normal sediments on its flanks." The Devonian reefs of the Traverse Bay region comprise "conglomeratic beds, while within the thicker beds themselves the phenomena of contemporaneous erosion, of the wedging out of strata, and, occasionally, of cross-bedding, and ripple-marks are met with. Indeed, all the phenomena seen in heavy bedded sandstones are found in these fragmental deposits." In the Onondaga reef of Williamsville, New York, "the corals of the bedded limestone in the neighborhood of the reef are fragmental and indicate considerable wave activity around the margins of the reef." From these data the conclusion is forced that the Silurian reefs of Gotland and Cedarburg, Wisconsin; the Devonian reefs of Alpena, Michigan, and Traverse Bay, Wisconsin, and the Onondaga reef of Williamsville, New York, were formed in water so shallow that they were within the influence of surface waves. An examination of the types of organisms composing these reveals that massive corals, such as *Stromatopora*, *Favosites*, *Acervularia*, etcetera, are important. Professor Schuchert informs me that he has seen in the Devonian reefs at Louisville, Kentucky, heads of *Cyathophyllum* "probably not less than 8 feet across," and near Alpena, Michigan, *Stromatopora* heads "that were certainly not less than 12 feet in diameter." As the reef-building organisms of Paleozoic time consist of *Stromatopora* and its allies, of *Favosites*, of masses of Alcyonarians, as *Halysites*, and massive *Rugosa*, the opinion seems justified that all Paleozoic reefs were formed in very shallow water, as it is probable that closely related organisms of the same facies lived under similar conditions.

The application of both the criteria derived from a study of Recent coral reefs and from a study of the sediments in which the Paleozoic coral reefs are inclosed leads to the same conclusion, which is, that Paleozoic coral reefs were formed in shallow water, often or usually at a depth not greater than that of the possibility of wave action. It seems that 25 fathoms may be considered a safe maximum of the depth for their formation.

The intensity of the light on the Paleozoic reefs is a corollary of the depth. Sunlight can penetrate beyond 25 fathoms in depth; therefore the Paleozoic reef corals lived within the region of strong light; and the opinion is ventured that the intensity of the light was a controlling factor in limiting the distribution of these organisms in Paleozoic time, as it is at present.

TEMPERATURE

In summarizing the data on the conditions in which modern reefs are formed, it was stated that the annual minimum temperature must not be below 68 degrees Fahrenheit and that the annual mean temperature must be above 70 degrees Fahrenheit. In the quotation given from Sir John Murray on the influence of temperature on the secretion of calcium carbonate by marine organisms is the statement:

"It thus appears that the most favorable conditions for lime-secreting organisms are met with in the warm, equable tropical waters of the ocean, and here, as a matter of fact, we find the greatest development of corals and the largest number of lime-secreting pelagic organisms. In the polar areas and in the cold water of the deep sea there is, as is well known, a feeble development of all carbonate of lime structures in marine organisms."

A high temperature is necessary for vigorous organic metabolism and facilitates the secretion of carbonate of lime. The size of some of the Paleozoic coral heads indicates how vigorous was this secretion by the Paleozoic zoophytes. From an examination of modern reefs and a study of the conditions favorable for the organic secretion of large masses of the carbonate of lime, the deduction seems safe that the Paleozoic coral reefs were formed in water of rather high temperature, the annual minimum not being lower than a temperature between 60 and 70 degrees Fahrenheit: and the annual mean, probably above 70 degrees Fahrenheit.

MOVEMENT OF OCEANIC WATERS

That the waters surrounding the Paleozoic reefs were in motion, not stagnant, needs only brief discussion. That the waters were agitated is indicated by the coarseness of the sediments on some of the reefs and by such phenomena as ripple-marking.

CHARACTER OF THE BOTTOM

For modern reefs a comparatively clean and rather firm bottom is necessary for the growth of zoophytes. The organisms need proper basal support, and the accumulation of fine sediment is fatal to them. We may be confident that similar conditions were necessary in Paleozoic time.

COMPOSITION OF THE OCEANIC SALTS

An opinion on the composition of the oceanic salts in the Paleozoic era can not be based on any very definite evidence, but there seems no

special reason, perhaps, excepting very early stages in the earth's history, why the composition of the salts in solution in the ocean should have varied from one geologic age to another. Because of the lithologic similarity of material in suspension laid down as sediments in the oceans from Paleozoic to Recent time, it appears probable that the material in solution was also similar throughout the geologic ages. The marine organisms of the earlier geologic ages, although different from those of the later, represent the same zoologic groups, and their skeletons indicate the extraction of salts from the medium in which the animals lived by similar physiologic processes. The available evidence indicates that the oceanic salts in Paleozoic time were not essentially different from those of the ocean of today.

SPECIFIC GRAVITY

There are no means of directly obtaining light on the specific gravity of the oceanic waters in Paleozoic time, but we may reach an opinion on the subject through inference. The specific gravity of ocean water is determined by the quantity of salts in solution, and of these the calcium salts are important. As the Paleozoic lime-secreting organisms required calcium salts to be in solution in the medium in which they lived, a specific gravity of the oceanic water considerably above that of pure water was necessary. Although a quantitative estimate can not be given of the specific gravity of Paleozoic oceanic waters, it may be stated that salts were contained in solution, calcium salts were important constituents, and it appears probable that there has been no great variation in the specific gravity of the water of the ocean since that time.

SUMMARY

All the data obtainable from various sources indicate that the Paleozoic coral reefs were formed under conditions similar to those under which Recent reef corals live.¹¹

The conclusions may be summarized as follows:

- (a) Depth, maximum, 25 fathoms; light, strong.
- (b) Temperature, annual minimum not lower than between 60 and 70 degrees Fahrenheit and probably above 70 degrees Fahrenheit.
- (c) Water, agitated and circulating.

¹¹ Bonney says in his appendix to Darwin's "Structure and distribution of coral reefs," p. 381: "Moreover, the *aporosa* and *madreporaria*, which are now the chief reef-builders, have only become common since the conclusion of Paleozoic ages, so that the largest volume of the geological history of the earth is excluded from consideration, because in the time which it covers the habits of the reef-builders may have been different." The evidence here presented shows, in my opinion, that the habits of reef-building corals have always been similar.

- (d) Bottom, clean or relatively free from deposits of silt.
- (e) Composition of the oceanic salts, probably the same as in the ocean of the present day.
- (f) Specific gravity of the oceanic waters, probably about as in the ocean of today. Certainly the specific gravity was high enough to furnish the large quantities of calcium salts demanded by the reef organisms for the formation of their skeletons.

*BEARING OF THE PALEOZOIC BRYOZOA ON PALEOGEOGRAPHY*¹

BY E. O. ULRICH

The Bryozoa undoubtedly lead all other Paleozoic invertebrates except the Ostracoda in abundance of individuals, and probably also in specific differentiation. They occur more or less profusely in all kinds of deposits save in the coarser quartzose sandstones and in black shales. They seem to have preferred waters depositing slightly argillaceous limestone. Like their recent representatives, they flourished best in relatively quiet waters and at depths little beyond the zone of violent wave action. In their mature development and habits of growth they are essentially bottom-dwelling sessile organisms, their calcareous colonies being attached to stones, dead shells, and other foreign objects. It is for this reason that they are absent or rarely found in black shales, in which littoral, and in fact bottom-dwelling invertebrates of all sorts, are similarly infrequent. Although usually fixed in their mature stages of growth, their larval forms are free-swimming, and this fact, doubtless, accounts for the great geographic distribution often attained by species of this class. It also suggests that their dispersal, which was greatly facilitated by currents, took place rapidly, and in this lies their great value as horizon markers. In fact no other group of organisms has proved of greater value in stratigraphic correlation.

In general aspect bryozoan colonies vary exceedingly. Some form masses several feet in diameter and grow so profusely as to almost rival the corals in reef-building. Some are hemispheric, others twiglike or bushy, but more of them, especially of the middle and late Paleozoic species, form very delicate lacelike fronds or incrustations.

The Bryozoa seem to have originated in the Caribbean Sea or Gulf of Mexico, the oldest representative being a species of *Nicholsonella*, found in Canadian rocks in northern Arkansas, laid down by waters invading

¹ Manuscript received by the Secretary of the Society May 23, 1911.

the Mississippian embayment. The prevailing types in the Ordovician, in which deposits they for the first time attain any considerable abundance, belong to the solid massive forms known as the Trepotomata. Beginning with the Silurian, the lacelike Fenestellidæ, a large family of the Cryptostomata, become by far the most abundant representatives of the class. The bifoliate Cryptostomata began early in the Ordovician and continued practically to the close of the Paleozoic, while the Cyclostomata, which are likewise old, continue to the present. The Trepotomata, including mainly massive and branching colonies, have been of the greatest service in stratigraphic correlation. This is, first, because of their great abundance and widespread distribution, and, second, because of the certainty and relative ease with which the species can be positively determined by means of thin-sections. Even small imperfect specimens can be determined beyond doubt. The bifoliate Cryptostomata are of nearly equal service, but in these the shape and surface characters are of more importance, requiring greater perfection in preservation to insure positive determination. As to the Fenestellidæ and other delicate types, whose discrimination depends solely on easily effaced surface characteristics, these are of correspondingly less practical value for stratigraphic purposes. However, at their worst, a long experience among the Paleozoic fossils has shown that the Bryozoa compare favorably as guide fossils with any other class of organisms.

Considered in their paleogeographic bearings, the abundance of the Bryozoa and their occurrence in nearly all kinds of deposits may be said to establish the prevailing shallowness of the continental seas in which they flourished, while a comparative study of the species shows differences in geographic distribution which can be attributed only to localization of origin and development and dependence on currents for their transportation. In some cases many genera are represented only in faunas which can be traced to invasions of a particular sea. The latter is of especial importance in paleogeography, in that their abrupt geographic limitation suggests considerable detail in the pattern of the continental seas and lands. For example, regarding certain clearly discriminated faunas found in sediments that wedge out northwardly by overlap, we may be certain that they invaded through some opening in the south. Further, we may infer that the origin and dispersal of the fauna lies in one of the permanent oceanic basins in that direction. On the other hand, if beds and faunas extend and terminate in a similar manner in a southward direction, the sea in which the fauna originated and developed is for like reasons located to the north. We then have introduced into the

geographic pattern of some particular time period continental basins connecting in the case of North America with the Arctic on the north, the Atlantic and Pacific on the east and west, and still others that were occupied by waters invading from the Gulf of Mexico.

Possibly these different oceanic waters contributed to continental basins at the same time, but as a rule this would seem to be highly improbable. Instead it is thought that when seas were entering the southern border and filling certain continental basins the northern waters were excluded. Whether solely by tilting of the surface of the continent, or whether abundant heaping of oceanic waters toward the equator and then back to the poles contributed in any marked degree, is not readily determinable and is, after all, beyond the scope of the present paper. Under this conception it follows that the same basin often contains superposed deposits and faunas originating in the Arctic, the Atlantic, and the Gulf of Mexico, and occasionally, as in Oklahoma, in waters from all four sides.

The Paleozoic basins now included within the Mississippi Valley usually alternated between the Gulf of Mexico and Arctic waters, but these, so far as known, were never present at the same time and therefore never mingled. In the Appalachian region, however, where Gulf and, more rarely, Arctic waters alternate with Atlantic invasions, confluence of the first and last and consequent mingling of the faunas is occasionally suggested.

However, even in these instances the community of species in otherwise typical north Atlantic and Gulf faunas may be more plausibly explained on the assumption that these species ranged in the south Atlantic as well as the north Atlantic, hence invaded from both directions. Therefore, without going into a detailed statement of the facts on which the opinion is based, it is concluded that the several oceanic waters and faunas seldom if ever intermingled within continental basins.

As said, the Bryozoa began to constitute a very considerable proportion of the marine faunas of the continental seas in the middle Stones River, a group of Ordovician rocks that is well developed in central Tennessee and attains much greater thickness in the Appalachian Valley. The Bryozoa are especially abundant in the Pierce division of the group, a bed with a maximum thickness of 27 feet in central Tennessee, but attaining much greater dimensions in the southern Appalachians. The Bryozoa characterizing the Pierce consist chiefly of bifoliate *Cryptostomata* belonging to the *Ptilodictyonidae* and *Rhinidictyonidae*. In central Tennessee, also in the southern Appalachians in Alabama and eastern Tennessee, these forms are exceedingly abundant, but in following the beds northward in the Appalachian Valley they rapidly diminish in num-

ber until they are practically absent throughout the corresponding part of the formation in Virginia, West Virginia, and Pennsylvania. Whatever reason may be assigned for this northward diminution, the fact remains that they are abundant in the south. Hence the inference is plain that they must have been derived from that direction—in other words, from the Gulf of Mexico and perhaps other contributory seas lying beyond it. Other evidence tending to the same conclusion is that very similar species of Bryozoa, about whose derivation from the preceding Pierce fauna there can be no question, occur in the Lebanon, an upper Stones River formation, and again in the Lowville, the first of the deposits of the Black River group. The Lebanon Bryozoa, like those of the Pierce, diminish rapidly northward in the Appalachian Valley; the Lowville much more slowly, so that a very fair representation of the Tennessee species of this formation is recognizable as far north as New York and Canada. From this point westward to Minnesota they rapidly diminish in number. Following the Lowville southward from Minnesota we find that the Bryozoa, like the corals, are almost entirely absent.

The three invasions of Bryozoa so far mentioned are undoubtedly from the south. Doubtless the distribution of these organisms in the continental basins was favored by warm currents entering the inland seas from the oceanic basins contributing the water. As previously stated, the migration of the Bryozoa is largely confined to this mode of dispersal. Considering the limited geographic distribution of the Pierce and Lebanon Bryozoa, the invading currents must have been of relatively small importance in those seas. Physical data bearing out this view are at hand. The wider distribution of the Lowville types suggests perhaps more active and certainly longer sustained currents.

That these currents passed up chiefly along the east shore of their respective seas is likewise suggested by the distribution of the Bryozoa. So far as known, Bryozoa are entirely absent in the Stones River rocks of northern Arkansas and Missouri, and either very rare or totally absent along the western, northern, and eastern shores of the basin as far as southern Virginia. As stated, the Bryozoa are also very abundant in the Lowville, and that here again their number becomes less and less away from the southeastern shore until in Missouri but a single species remains, and this owes its presence to its parasitic habit on a shell whose migration was less dependent on currents.

Similar conditions of migration by currents is suggested by the Bryozoa and corals of late Paleozoic ages. It is especially well marked by the Onondaga Bryozoa, which are abundant all along the eastern shore up to Ontario, but are almost entirely wanting on the flanks of the Ozark up-

lift, which form a part of the western shore. The significance of such facts are apparent when we note the relatively short distance separating Missouri and southern Illinois from the Nashville and Cincinnati domes, and the much greater distance between western Tennessee and Ontario, along which the deposits of this age are filled with Bryozoa and corals.

From the facts just stated it is inferred that a marine current entered from the Gulf and, hugging the eastern shore, carried the free-swimming larvæ of these sessile types as far as it was competent. In the case of the Stones River this current seems to have spent its force before reaching Virginia. In the other two cases, the Lowville and Onondaga, the current continued on through New York and Ontario.

More or less similar invasions of southeastern American continental basins occurred in succeeding Paleozoic ages. Notable among them is the early Trenton Wilmore limestone fauna, which contains a number of Bryozoa ranging from Kentucky to Canada; second, the late Eden and Maysville faunas, which contain numerous forms in zones which can be followed up the Appalachian Valley from Tennessee to New York and southern Ontario, where they are represented in the Lorraine formation; and, third, the late Clinton Rochester shale, which has a similar distribution. A somewhat different distribution of bryozoan faunas invading from the south is shown by the earliest Clinton, which extends, like the Lorraine preceding it, from Tennessee to southern Canada in a northeasterly direction, but also extends to Oklahoma in a western direction. The Helderbergian fauna, which includes many Bryozoa, is a good example of a southern Atlantic fauna invading separate continental basins, in the one case through the Mississippi embayment, and in the other from the middle Atlantic to the Appalachian troughs by way of an inferred opening at Chesapeake Bay.

Finally, the late Tennessean Chester Bryozoa, which passed northward in and across the Atlantic to England, where they are represented in the Mountain limestone, and which, on the American side, spread through the continental basins of southeastern United States from northern Arkansas to Maryland.

The invasions from the north—that is, from the Arctic basin—are similarly and no less readily discriminated than are the southern invasions. Like them, the faunas range as far south as their respective beds extend, terminating their geographic distribution when these beds wedge out by overlap. There are two important Ordovician bryozoan faunas which evidently originated in the Arctic and spread southward into the basins of North America. The first of these is best known from the late

Black River or Decorah shales of Minnesota and Iowa. It has been recognized also at a number of localities in eastern British America and extends southward in the Mississippi Valley to central Kentucky and northern Tennessee. In the latter two States the fauna, which is in everywise typical, has been noted at only a few localities. Where observed the bed is only from an inch to 2 feet in thickness and is limited above and below by formations containing totally different faunas of southern origin. Further, the upper and lower boundaries of this bed exhibit clear evidence of interrupted deposition. Moreover, these extreme southern wedges of the Decorah shale seem to be entirely confined to shallow hollows in the underlying Lowville limestone. The facts are essentially similar with respect to the second of these Arctic faunas, the main difference being that whereas the first is entirely unknown, at least in the *northern* Appalachian region, the second is locally developed in central and eastern New York and extends thence southward into New Jersey. Like the first, it is best developed in southern Minnesota and northern Iowa, where it is found in the Prosser limestone, the proposed name of a formation comprising the Clitambonites, Nematopora, and Fusispira beds of the Minnesota reports. The third Arctic fauna is early Silurian in age and belongs in the Richmond series. It is marked especially by corals and Bryozoa, both of a decidedly Silurian aspect. It is known in Baffinland and Alaska, and is locally found on this continent to the south as far as southern Illinois, where it is included in the Noix oolite or Edgewood beds. In the far West it is widely distributed, being known in Arizona, Utah, New Mexico, and western Texas.

That these forms really originated in the Arctic basin is indicated not only by their distribution in North America, but also by the fact that they are similarly developed in the Baltic province of Europe. As has been clearly shown by studies of the Baltic Bryozoa just completed by R. S. Bassler, a large proportion of species described from these beds in Minnesota and elsewhere in America are represented by identical and very closely allied species in Russia. Up to date 70 out of 143 Minnesota species of this class are found also in Russia.

To sum up, the Bryozoa have an exact bearing on paleogeography (1st) because of the abundance of their fossil remains, (2d) because of the certainty and comparative ease of ascertaining the critical characters, (3d) their indication of the shallowness of the seas in which they lived, (4th) their rapid and wide dispersal, justifying conclusions respecting the essential contemporaneity of their occurrence, and (5th) the light they throw on the direction and extent of marine currents.

PALEOGEOGRAPHIC AND GEOLOGIC SIGNIFICANCE OF RECENT BRACHIOPODA¹

BY CHARLES SCHUCHERT

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NUMBER AND RANK OF RECENT BRACHIOPODS

There is no class of living shelled animals better known as to their structure, habitat, and geographical distribution than the Brachiopoda. They have been persistently dredged for because of their rarity by many exploring vessels, in all seas and in all depths, and have been studied by many workers, chiefly in Europe, America, and Japan. A careful study of the rather diffuse literature² reveals 166 more or less well known

¹ Manuscript received by the Secretary of the Society May 23, 1911.

² The information here given has been gathered from many sources, but the more important works are as follows:

Beecher: Revision of the families of loop-bearing Brachiopoda and development of *Terebratalia obsoleta* Dall; Trans. Conn. Acad., 9, 1893.

Blochmann: Untersuchungen über den Bau der Brachiopoden, Jena, 1892 and 1909.
Neue Brachiopoda d. Valdivia u. Gauss Expedition, Zool. Anzeiger, 30, 1906. Zur Systematische u. Geographische Verbreitung d. Brachiopoden, Zeit. f. Wiss. Zool., 90, 1908.

Buckman: Antarctic fossil Brachiopoda, Schwedische Südpolar-Expedition, 1910.

Dall: Many papers from 1870-1909.

Davidson: A monograph of recent Brachiopoda, Trans. Linnæan Soc. London, 4, 3 parts, 1886-1888.

Hall and Clarke: An introduction to the study of Brachiopoda, Rep. N. Y. State Geol., 1894.

Schuchert: A synopsis of American fossil Brachiopoda, Bull. U. S. Geol. Surv., 87, 1897.

Yatsu: Notes on the histology of *Lingula anatina*, Jour. Coll. Sci., Imp. Univ., Tokio, 17, 1902. Habits of the Japanese *Lingula*, Annot. Zool. Japonenses, 4, 1902.

forms, and these are distributed in 33 genera. Of these about 8 forms are poorly defined, so that there are at least 158 established species of living brachiopods. However, with the refined methods recently introduced by Blochmann and Dall, and in the further dredging that is now going on in Antarctic waters, we may expect a considerable increase in the number of species, so that eventually there may be a total of about 180 forms. Whatever the additions may be to our knowledge, that in regard to their habitats, bathymetric and geographic range will be slight. We therefore have safe guidance in the living members of the class as to what the bathymetric range and habitats of the fossil forms were.

The 158 living forms are grouped according to their relationship as follows: Of Inarticulata there are 29 and of Articulata 129. The inarticulate brachiopods are nearly equally distributed among the orders *Atremata* (15) and *Neotremata* (14), there being of *lingulids* 15, *discinids* 7, and of *Crania* 7. Of the once wonderfully prolific Paleozoic order *Protremata* there are but 2 living representatives in *Thecidium*, a genus that arose in the Cretaceous. They are small forms, and though not rare in the Mediterranean and Antillean regions, are restricted to a depth ranging between 30 and 300 fathoms. Both also occur fossil since the Miocene or Pliocene, and are therefore morphologically static. The *Telotremata* are the dominant brachiopods, being represented by 15 *rhynchonellids* and 112 *terebratulids*, and of these the last named had far less differentiation in the Paleozoic. Both stocks are very ancient, the *rhynchonellids* being as old as the Middle Ordovician and the *terebratulids* arising early in the Devonian. While neither stock was prolific in genera and species throughout the Paleozoic, both stocks began to evolve in the late Triassic, and in the Upper Jurassic the seas swarmed with a great variety of these animals, and especially of the *terebratulids*. The decline of the latter began in the Cretaceous and persisted to the Oligocene, when the warm waters of this time seem to have rejuvenated the stock to its present good representation. On the other hand, the *rhynchonellids* have maintained their generic and specific variation fairly constant since the Silurian, when for the first time the stock was well established. In the Jurassic, however, they were more abundant than at any other time. We learn, therefore, that though these two stocks are very old, they are still morphologically young and plastic, constantly giving rise to new forms and new genera.

BATHYMETRIC RANGE

IN GENERAL

The bathymetric range of the 158 species is as follows:

Five, or 3 per cent, are restricted to the strand-line (3 Inarticulata, 2 Articulata).

Forty-four, or 28 per cent, range from the strand to about 90 feet (21 Inarticulata, 23 Articulata).

Sixty-three, or 40 per cent, range from 90 to 600 feet (7 Inarticulata, 56 Articulata).

From the strand to 600 feet occur nearly 71 per cent of the living brachiopods, or 112 forms.

Seventeen, or 10 per cent, range from 600 to 1,000 feet (all Articulata).

Eleven, or 7 per cent, are deep-water forms below 1,000 feet, but adjacent to continents (all Articulata).

Eighteen, or 11 per cent, are deep-sea forms situated near continents (1 Inarticulata, 17 Articulata).

Of typical deep-sea mid-oceanic forms ranging from 200 to 2,465 fathoms there are 5.

Of the 158 recent species, at least 10 are practically restricted to the area between tides. These are *Laqueus* (?) *aleuticus*, *Magellania flavescens* (goes down to 14 fathoms), *Megerlina davidsoni* (in an extinct volcanic crater), *M. lamarckiana* (goes in deeper water), an uncertain species of *Terebratalia* (?) *radiata*, *Lingula anatina* (there are probably other species of this genus), *Discina striata*, *Discinisca cumingi* (down to 8 fathoms), *D. lamellosa* (to 10), and *D. strigata*.

Between low-water mark and above 90 feet of depth the great majority of inarticulate brachiopods live, or 21 species out of a total of 29 (*Lingula*, 11; *Glottidia*, 4; *Discina*, 1; *Discinisca*, 4; and *Crania*, 1). Of the articulate brachiopods, 23 out of the 129 live in these shallow waters, and of those but 7 continue their range below 100 fathoms (*Bouchardia*, 1; *Dallina*, 1; *Dyscolia*, 1—goes down to 250 fathoms; *Frenulina*, 1; *Gwynia*, 1—goes down to 2,000; *Kraussina*, 1; *Laqueus*, 3; *Liothyrida*, 1 down to 600, 1 down to 1,300; *Macandrevia*, 1 down to 1,400; *Terebratalia*, 1; *Terebratella*, 6—1 down to 120, and *Terebratulina*, 4—1 down to 1,170).

From 90 feet and down to 600 feet there appear (with one exception) all the remaining species of inarticulate brachiopods, 7 in number (*Discinisca*, 1; *Crania*, 6). Of the articulate forms, 56 appear here for the first time, and of these at least 23 continue into still deeper water (*Agul-*

hasia, 1; Cistella, 6; Cryptopora, 2; Dallina, 3; Hemithyris, 6; Laqueus, 4; Liothyryna, 6; Magellania, 4; Megathyris, 3; Mühlfeldtia, 3; Platidia, 2; Terebratalia, 4; Terebratella, 3; Terebratulina, 7, and Thecidium, 2).

Below 600 feet and above 1,000 feet appear 17 additional articulate species (Acanthothyris, 1; Cistella, 3; Dallina, 2; Hemithyris, 1; Kraussina, 4; Liothyryna, 2; Macandrevia, 2; Platidia, 1, and Terebratulina, 1).

There are 11 deep-water forms, not one of which extends above 1,000 feet of depth or goes into the abyss. As a rule they are, like the abyssal forms, thin-shelled animals, but do not average as small as the true deep-sea species. These are the rhynchonellids *Hemithyris gerlachi* (243-270 fathoms), *H. racovitzae* (270), and *Basilola beecheri* (200-313), occurring off western Hawaii; the terebratulids, *Dyscolia wyvillii* (385-845), *Liothyryna antarctica* (385), *L. sphenoidea* (215-1,090), *L. subquadrata* (500-600), *L. winteri* (360), *Mühlfeldtia echinata* (346-423), *Platidia* (?) *incerta* (390-1,120), and *Terebratulina valdiviae* (392).

Of typical abyssal forms that have strayed far from the continents there are but five: the discinid *Pelagodiscus atlanticus* (200-2,465); the rhynchonellid *Hemithyris strebli* (2,035-2,084); the terebratulids *Chlidonophora chuni* (865-1,220); *C. incerta* (292-1,850), and *Liothyryna* (?) *wyvillii* (1,035-2,900). To these must be added 13 other forms that are also abyssal in habitat, but are still situated close to the continents. These are the rhynchonellids *Hemithyris craneana* (1,175); the terebratulids *Frieleia halli* (599-984), *Eucalathis* (the 4 species of this genus, 300-2,588), *Liothyryna clarkeana* (1,175-2,035), *L. mosleyi* (210-2,222), *Macandrevia craniella* (1,175), *M. diamantina* (1,175-2,222), *M. tenera* (1,450), *Magellania wyvillii* (2,160), and *Terebratulina* (?) *dalli* (1,875). All of these abyssal species are small in size or below the average of their genera, and have very thin, fragile shells.

These figures giving the bathymetric range of recent brachiopods teach us that fully 80 per cent inhabit waters shallower than 1,000 feet, and over 70 per cent live above 600 feet. Brachiopods therefore are, as a rule, significant of shallow water and of continental or epicontinental seas.

INARTICULATA GENERA

Let us now examine into the detailed bathymetric range of the 33 living brachiopod genera, to see if anything can be learned from their distribution that will give guidance as to the depths at which the fossil forms lived. We have seen that but 5 species are restricted to the strand-

line, but that in water less than 90 feet deep there occur about 49, or 31 per cent, of all living brachiopods. The most conspicuous of these shallow-water forms are of *Lingula* and *Discina*, genera that are restricted to the littoral region—that is, ranging from the strand-line to a depth of probably not much more than 60 feet. In addition to this, many of the species of lingulids occur in bays and estuaries, indicating that they prefer a habitat more or less freshened by land waters. *Disciniscia* also lives in the littoral region, but apparently never on the strand-line, and no species goes beyond 216 feet of depth. *Glottidia* commences at lowest tide, and has been taken as far down as 360 feet. *Crania* is not reported from the tide-line, but begins in 12 feet of water, and extends its bathymetric range to 808 fathoms. Of all the living inarticulate brachiopods, but one is completely habituated to deep water—*Pelagodiscus atlanticus*—which has a range from 200 to 2,425 fathoms. It is also a cold-water species, and its geographic range appears to be now or to have been world-wide, for it is known in the north and medial Atlantic Ocean, the Pacific, and off Australia. In its arm structure it is also very primitive, in that the brachia are not spirally rolled, but “form two simple loops, with no spirals whatever” (Dall, 1907). In other words, the brachia are in the schizolophus stage, as defined by Beecher,³ and therefore do not develop into the more complicated structures seen in most living brachiopods.

A survey of the geographic distribution of the inarticulate brachiopods also shows that all the littoral and shallow-water species are bound to warm waters, and that hardly any are common to two zoological provinces. Furthermore, when the shallow-water and littoral forms are compared with those of the deeper, and especially the one species of abyssal waters, we note that the former are decidedly more prolific in numbers, are often considerably larger and always have thicker shells, while the deeper water forms are nearly always smaller and have thin and nearly transparent valves. The smallest form with the thinnest valves is the abyssal *Pelagodiscus atlanticus*.

These results are of the greatest value to the paleogeographer, for they can be successfully applied to the fossil Inarticulata, and through this knowledge one can state positively the depth of water at which the fossil lingulids and discinids lived. Further, they are excellent guides as indicators of shorelines, and as such give clear guidance to the paleogeography of any given time.

The paleontologist finds that the greatest number of large, thick

³ Beecher: Bull. U. S. Geol. Surv., vol. 87, 1897, p. 108.

shelled specimens and the greatest variety of species of lingulids and discinids are found in shales and sandstones, and, furthermore, that the physical evidence of the deposits in which such occur is in harmony with the character of the sediments and the present distribution of the littoral and shore living inarticulates. On the other hand, it is not at all rare in the older Paleozoic deposits to find lingulids and discinids in limestones and dolomites, and when the specimens are large and thick shelled, even though they occur in such organic deposits, they give unmistakable evidence of very shallow-water conditions and a hint that the shore may not have been very far away. Small and thinner shelled species are also frequently seen in limestones and shales, but the associated animals and the character of the strata demonstrate that these also are shallow-water forms. On the other hand, in black shale deposits (Utica, Marcellus, Genesee), and more rarely in thin zones of black limestones (Marcellus, Genesee) is frequently seen an abundance of very small and even minute species of obolids, lingulids, and discinids that could not have lived on the bottom of these "Black Seas" with their carbonaceous or even sulphurous depths. Nor can their size and frailty be taken as evidence for deep-sea deposits, for they are manifestly of the surficial waters of a sargasso-like sea, where in all probability they lived attached to floating algæ. In such deposits the evidence of the associated animals is that they are either floaters (graptolites, or spore cases of algæ), or swimmers (pteropods as Styliolina, cephalopods as Endoceras, nautilids and goniatids), or commensal floaters anchored to other suspended organisms as the byssally attached thin shelled and modified bivalves described by Clarke from the Genesee of New York.

It is also desirable to point out here the wonderful vitality of the living inarticulate brachiopods. *Lingula* is exposed on the tidal flats of Japan for hours without injury, and on account of its accessibility is regularly gathered by the poorer people for food. At high tide these animals are covered with 3 to 4 feet of water. Their habitat may be brackish or foul with decomposing organic matter, even to such an extent that all other shell fish may be killed off, but *Lingula* will continue to live under such adverse conditions. Yatsu, who has studied living *Lingula*, tells us that on little estuaries in certain bays of southern Japan their habitats may be covered by sand and mud brought down by stream freshets, so that all of the burrowing shell fish will be destroyed, but *Lingula* will still live in such stinking places and the individuals tunnel themselves to the surface. The burrows are from 2 to 12 inches long, and the movements of the animals up and down in the holes are made by means of the highly contractile and regenerative peduncle. It is thought that *Lingula* may

attain an average age of 5 years or even more. Yatsu kept them alive in aquaria with the water fetid, and Morse did the same, keeping his specimens alive for six months in almost unchanged water. Joubin kept *Crania*, taken from great depths, alive in jars under very adverse conditions for 14 months. In these statements we see the very adverse conditions under which the burrowing *Lingula* may live, and that the tenacity of endurance is also very great with cemented *Crania*. In this adaptability lies the probable explanation of why the lingulids and craniids have lived since the Ordovician. *Lingula* and *Crania* have endured all of this vast time apparently without change other than the superficial ones of form, size, and ornamentation.

We may therefore conclude that inarticulate brachiopods when large, thick shelled, and abundant clearly indicate to the paleontologist animals inhabiting very shallow waters of probably less depth than 100 feet. Further, that these waters were in close proximity to the shores and probably were warm. *Crania* is the only genus inhabiting shallow waters of the cooler areas and essentially those of the northern hemisphere. The immediate shoreline, and often the estuarine bays and deltas, will be indicated especially by the large lingulids embedded in muds and sands with an otherwise sparse fauna. When the species are small, but not minute, still somewhat thick shelled and the individuals abundant, it is probable that the sediments of such waters were also those of the shallows—that is, ranging between 50 and 200 feet, with the possibility of even 400 feet. Minute inarticulates are not safe guides to bathymetric depth in Paleozoic time, and their habitat significance must be judged more from the associated fossils and the character of the entombing sediments. The *Atremata*, after the Cambrian, appear always to have preferred shallower waters near the strand-line, while the *Neotremata*, though also lovers of shallow waters, appear to have preferred to keep away from the immediate strand. These slightly varying habitats have their probable explanation in that all the *Atremata*, after the Cambrian (lingulids), lived in burrows, while those of earlier times (obolids) appear to have lived above the bottom, fastened to foreign objects by a more or less long peduncle. On the other hand, the *Neotremata* are never burrowers, but are fastened to some object above the ground by a very short peduncle that issues directly through some part of the ventral valve, as in the highly modified bivalve *Anomia*. We see, therefore, that the burrowing lingulids are protected from wave action, and that their holes are always full of water, while the discinids live above the bottom, and because of their very much cramped shell space would, at low tide, be without water for hours. Further, the peduncle in *Lingula* and the

Atremata is a burrowing and prehensile organ, while in all other brachiopods it is for permanent attachment to a given place. It is true that some discinids do approach the strand, but as they have a more or less centrally placed short and pluglike peduncle and a conical upper valve the waves can have little effect in pulling them from their anchorages. On the other hand, in the articulate brachiopods the peduncle is more or less long and emerges from one valve, so that the animals hang loose at one end of the stalk, a decidedly disadvantageous mechanical defect for holding in tumultuous waters. It is probably for these reasons that most brachiopods avoid the tearing strand-line, and are most abundant in the quiet waters between 50 and 500 feet.

ARTICULATA GENERA

None of the articulate brachiopods can be relied on to indicate the strand-line, as but 5 approach or live in this zone, and but a single genus appears to be restricted to very shallow water (*Megerlina*, with its 2 species). The other 3 forms prefer deeper water. Of the 129 articulate species about 19 per cent (25 species) live in less than 90 feet of water. Their real habitat, however, is in the deeper water between 90 and 600 feet, where nearly 46 per cent (59 species) live. Down to 600 feet occur 84 articulate and 28 inarticulate forms, or, in other words, more than 70 per cent of brachiopods are at home in these shallower waters. We may, therefore, conclude that the greatest abundance of living brachiopods is in the stormless waters between 90 and about 500 feet of depth.

None of the 15 rhynchonellids live in very shallow water, nor are any reported in less than 90 feet, but as *Hemithyris psittacea* is thrown up on the Labrador coast by the storms it is probable that this form lives here not far from the strand-line. The living species are grouped in 4 genera, of which *Acanthothyris*, with 1 form (160 fathoms), *Basiliola*, with 1 form (200-313), and *Cryptopora*, with 2 forms (25-2,200), may be regarded as the deep-water genera. *Hemithyris* has 11 forms, and of these but 2 live between 90 and 288 feet, while the others range down to 2,084 fathoms. We therefore see that the rhynchonellids are now deep-water brachiopods, but this certainly was not the case during the Paleozoic, where they are frequently found in coarse sandstones, and not at all rarely in mudstones, associated with medium sized and thick shelled lingulids. Today they are found in nearly all parts of the oceans, from north of the Arctic Circle to far south in the Antarctic region. While most of the species live in cool waters, at least one (*H. cornea*) ranges from the warm water off Cape Vincent in 57 fathoms down to the cold waters off Cape Finisterre in 1,093 fathoms. *Cryptopora gnomon* has

been dredged in the warm waters off the Canaries in 50 to 65 fathoms, in the cool waters off the Azores in 2,200 fathoms, in the cold waters off Ireland at 1,443 fathoms, and in Davis Strait at 1,750 fathoms. While temperature does now somewhat restrict the geographic and bathymetric range of the rhynchonellids, still the majority seem to prefer the cooler and deeper waters. This the writer believes to be a modern adaptation that has come about since the Jurassic.

In regard to the geographic distribution, some of the species are locally restricted, others range through several provinces, and one (*H. psittacea*) is found throughout the greater part of the northern hemisphere.

The conclusion derived from the living rhynchonellids, therefore, is that they give no satisfactory guidance as to the bathymetric distribution of the fossil forms. In regard to their geographic occurrence, the Paleozoic distribution is very much like that of the living forms, and very little safe guidance is therefore to be derived from them as provincial indicators. Extinct species of the same genus may have local or very wide distribution, may be restricted to a geologic zone of but a few feet in thickness or range through the greater part of a period (Devonic), but sometimes a single species will have a limited time range and yet be distributed over the entire North American continent (*Rhynchotrema capax*).

The terebratulids are in greatest abundance specifically and numerically in the shallower waters. Five occur between the tides and 76 out of the 112 forms, or 67 per cent, live in waters less than 600 feet in depth. The largest of all living species is *Magallania venosa*, growing to 3¼ inches in length and found in abundance in Magellan Straits at depths varying from 50 to 480 feet.

SHELL CHARACTERS OF DEEP-WATER SPECIES

The 29 deep-water and abyssal species are all thin shelled, often very fragile, gray or light yellowish in color, more or less transparent and generally small in size. There are, however, large species in the greater depths, but none in the abysses. Such are *Dyscolia wyvillii* (385-845 fathoms), with a length of 2.5 inches; *Liothyryna subquadrata* (500-600), with a length of 1.1 inches, and *L. sphenoides* (215-1,090), with a length of 1.2 inches.

GEOLOGIC HISTORY OF THE LIVING BRACHIOPODS

We will next examine into the geologic range of the 33 living genera of brachiopods. There are at least 23 having fossil representation, and

this is more than 60 per cent of the living genera. Two have lived since the Ordovician (*Lingula* and *Crania*), 6 since the Jurassic (*Acanthothyris*, *Eucalathis*, *Magellania*, *Megathyris*, *Terebratella*, and *Terebratulina*), 4 since the Cretaceous (*Agulhasia*, *Cistella*, ?*Discinisca*, and *Thecidium*), 1 since the Miocene (*Platidia*), 7 since the Pliocene (*Glottidia*, *Hemithyris*, *Dyscolia*, *Liothyryna*, *Macandrevia*, *Terebratalia*, and *Mühlfeldtia*), and 3 since the Pleistocene (*Bouchardia*, *Dallina*, and *Gwynia*). Of these 23 genera 6 have not spread into water as deep as 1,000 feet, these being *Agulhasia*, *Bouchardia*, *Discinisca*, *Lingula*, *Glottidia*, and *Megathyris*. Of genera that have spread beyond this depth, but which still have their best development in waters less than 500 feet, are *Gwynia*, *Magellania*, *Terebratalia*, and *Terebratella*. The genera having fossil representation, with their best development in the present seas at depths greater than 500 feet, are *Acanthothyris*, *Cistella*, *Crania*, *Dallina*, *Dyscolia*, *Eucalathis*, *Hemithyris*, *Liothyryna*, *Macandrevia*, *Mühlfeldtia*, *Platidia*, *Terebratulina*, and *Thecidium*. All of these are of long enduring stocks that had their rise at least as early as the Jurassic, and if we add to these the other truly deep-sea brachiopods, also of ancient phyla, but not known to have fossil representation, such as *Basiliola*, *Cryptopora* (both rhynchonellids), *Chlidonophora* (primitive terebratulid), *Frieleia*, and *Pelagodiscus* (discinid), we can say that the present deep-sea forms as a rule did not begin to migrate to this habitat earlier than the middle Mesozoic, and, further, that this adaptation is still going on. The truly abyssal forms, as *Basiliola*, *Chlidonophora*, *Frieleia*, and *Pelagodiscus*, are probably of stocks even older than the middle Mesozoic, and these genera may have begun their abyssal march as early as the beginning of the Mesozoic. It is, however, a noteworthy fact that of the great multitude of Paleozoic genera not one is known to have become wholly abyssal in its habitat; on the contrary, the two oldest Paleozoic genera that are still alive have not gotten far away from the strand-line. *Lingula* is still restricted to the littoral and *Crania*, while as a rule now a deeper water genus, is by no means restricted to the abyss, although it has been taken at 818 fathoms. These observations lead to the conclusion that the oceans probably did not begin to get exceedingly deep until after the great Appalachian Revolution toward the close of the Paleozoic—that is, early in the Mesozoic—and that this deepening has been going on since then. These views are also in harmony with the conclusion attained by Walther⁴ from a study of the life of the present deep seas.

⁴ Walther: Origin and peopling of the deep sea, Amer. Jour. Sci. (4), vol. xxxi, 1911, pp. 55-84.

Of the 158 living brachiopods but 25, or about 16 per cent, are also found fossil. None are older than the Eocene (*Megathyris decollata*); of the Miocene there are 4 additional species (*Dallina septigera*, *Platidia anomioides*, *Terebratulina caputserpentis*, and *Thacidium mediterraneum*). From the Pliocene there are 15 (*Cistella cuneata*, *Crania anomala*, *C. turbinata*, *Glottidia albida*, *Hemithyris nigriconis*, *H. psittacea*, *Liothyryna affinis*, *L. sphenoidea*, *L. vitrea*, *Macandrevia cranium*, *Mühlfeldtia echinata*, *M. truncata*, *Platidia davidsoni*, *Terebratella dorsata*, and *Thacidium barretti*); of the Pleistocene 5 (*Cistella cistellula*, *Dallina* (?) *spitzbergensis*, *Gwynia capsula*, *Magellania lenticularis*, and *Mühlfeldtia monstrosa*).

GEOGRAPHIC SITUATION OF RECENT BRACHIOPODS

IN GENERAL

All brachiopods without exception live in marine waters, and in the main their habitats are in the shallower waters bordering the continental masses. This is very clearly brought out in the "Chart of the world showing the distribution of the Recent Brachiopoda," by Hall and Clarke (1894, chart facing page 148), and in another by Blochmann (1908, plate 40), giving the distribution of the Liothyrynæ. These maps also show that but very few species have strayed far away from the continents in the truly abyssal regions. Only 5 have permanently adapted themselves to the great oceanic areas (*Pelagodiscus atlanticus*, *Hemithyris strebli*, *Chlidonophora chuni*, *C. incerta*, and *Liothyryna* (?) *wywillii*). With these should be considered 13 other forms which also inhabit great depths, but whose situation remains adjacent to the continents (see list on page 6). Then there are 11 species living permanently below 1,000 feet that may be spoken of as deep-water forms, but they are not as yet deep-sea animals, because their habitats are in connection with the continental shelves (see list on page 5). In other words, but 3 per cent of living brachiopods have permanently left the continental waters, a further 8 per cent are transitional between the abyss and the continental shelves, and an additional 7 per cent are still attached to the shallower waters of the outer parts of the continental shelves. This bathymetric distribution may be stated in still another way, namely, 81 per cent of living brachiopods are bound to the shallow waters bordering the land masses, 7 per cent are in the deeper waters of the continental shelves, 8 per cent are transitional to the oceanic areas, and 3 per cent are permanent inhabitants of the vast and cold Neptunic underworld.

The shallow waters about Japan have more brachiopods by far than any area of similar extent. Here occur 29 species in 12 genera; in other words, more than 18 per cent of recent brachiopods. In the Sea of Japan, or along the western side of the islands, there are 11 species, none of which seem to range deeper than 60 fathoms, and on the outer or Pacific side there are nearly twice as many kinds, or 20 forms, ranging all the way from shore habitats down to one at 160 fathoms. There is also one deep-sea form here at 1,875 fathoms, but at least 11 of the 20 occur in waters shallower than 100 fathoms. These Japanese species are the following:

*Brachiopods of the Sea of Japan (marked by a †) and the east coast of Japan (marked with a *)*

- | | |
|---|--|
| † <i>Lingula adamsi</i> (7 fathoms) | * <i>Terebratulina japonica</i> (48-55) |
| † <i>Lingula affinis</i> (0-1) | * <i>Terebratulina kiiensis</i> , widely distributed |
| † <i>Lingula anatina</i> (0-1), widely distributed | * <i>Terebratulina stearnsi</i> |
| † <i>Lingula jaspida</i> (7) | * <i>Dyscolia crossii</i> (100-250) widely distributed |
| * <i>Lingula lepidula</i> (10) | † <i>Dallina grayi</i> (7-37), widely distributed |
| * <i>Lingula smaragdina</i> (10) | * <i>Dallina mariae</i> (21-55) |
| * <i>Crania japonica</i> (71) | * <i>Dallina raphacilis</i> (100-200) |
| † <i>Disciniscia stella</i> (17-26), widely distributed | † <i>Terebratalia coreanica</i> (7-48) |
| * <i>Acanthothyris döderlini</i> (160) | † <i>Terebratalia gouldi</i> (60) |
| * <i>Hemithyris lucida</i> (48-100) | * <i>Laqueus blanfordi</i> |
| * <i>Hemithyris psittacea woodwardi</i> (35-48) | * <i>Laqueus (?) frontalis</i> |
| * <i>Liothyryna davidsoni</i> (55) | *† <i>Laqueus pictus</i> (23-55) |
| * <i>Liothyryna stearnsi</i> | †* <i>Laqueus rubellus</i> (1-35) |
| † <i>Terebratulina cumingi</i> | * <i>Frenulina sanguinea</i> (48), widely distributed |
| * <i>Terebratulina (?) dalli</i> (1,875), deep-water form | |

DISTRIBUTION OF THE GENERA

An analysis of the 33 genera shows that they are readily grouped into 5 great brachiopod areas or regions. These combine again into a deep-sea realm and 4 shallow-water geographical regions as follows: Boreal, Austral, Oceanica, and Gondwana. Each of these brachiopod areas will be discussed separately.

DEEP-SEA REALM

There are only 3 genera restricted to deep water, the discinid *Pelagodiscus* (200-2,425 fathoms) and the terebratulids *Chlidonophora* (282-1,850) and *Eucalathis* (300-2,588, Jurassic). The distribution of the two former is practically cosmopolitan, while the last one is re-

stricted to Atlantic Gondwana. Into this realm (below 1,000 fathoms) also enter the shallow-water genera *Cistella* (20-1,622, Cretaceous), *Cryptopora* (25-2,200), *Gwynia* (8-2,200, Pleistocene), *Hemithyris* (15-2,084, Pliocene), *Liothyris* (6-2,900, Pliocene), *Macandrevia* (5-2,222, Pliocene), *Magellania* (0-2,160, Jurassic), *Terebratella* (5-1,450, Jurassic), and *Terebratulina* (3-1,875, Jurassic).

BOREAL REGION

There are 6 genera typical of this region. Of wide distribution in northern waters is *Dallina*. It is best developed about Japan (3 species), and from here it probably spread into Arctic waters and along the eastern shores of the Pacific southward across Panama (previous to Upper Miocene time) into the Antillean region. In Arctic waters the genus occurs at Spitzbergen, and thence south to North Africa, but no relicts are found today in any of the Atlantic oceanic islands. *Laqueus* and *Terebratalia*, both also at home in the North Pacific, and probably as old as *Dallina*, did not get into the Atlantic by either the northern or Panama routes. *Acanthothyris*, widely distributed in the later Mesozoic, is now restricted to Japan.

Hemithyris is probably also of boreal origin where the family Rhynchonellidae is best developed since the Siluric. The present distribution of this genus is nearly world-wide, but with peculiar and extensive geographic lacunæ due to causes not yet understood. The genus has 11 species, and of these 5 occur in boreal waters, 4 in austral, 1 in Oceanica (*H. grayi*), and 1 (*H. strebli*) is a deep-sea form occurring in mid-Pacific. Of boreal species none occur off the United States or in Antillean waters. On the Pacific side of the two Americas but a single specimen has been taken in the Gulf of Panama (*H. craneana*) at a depth of 1,175 fathoms, and another form, *Frieleia halli*, occurs from San Diego, California, to Washington. *H. psittacea* is circumpolar in its distribution, attaining Japan (var. *woodwardi*; also *H. lucida*), Unalaska to Shumagins, Gulf of St. Lawrence, Norway south to Shetlands, and fossil even to Sicily. In the northeastern Atlantic occurs the non-plicate *H. cornea*. In Antarctic waters there are 3 species, with a fourth one in the New Zealand area. These forms seem to have spread from Japan south through Oceanica, and thence by way of New Zealand into Antarctica.

AUSTRAL REGION

There are 6 genera restricted to this region. Of more or less wide distribution in southern waters are *Agulhasia* (off South Africa), *Kraus-*

sina (off South Africa and Tasmania), Bouchardia (off Rio de Janeiro and abundantly fossil in Antarctica), Magellania and Terebratella (Chile, Magellan Straits, Patagonia, Australia, New Zealand, Tasmania, Kerguelens, and Antarctica). Megerlina seems to be restricted to the Australian region. There are other genera in these waters, and these are regarded as migrants to be discussed under Gondwana. This region is faunally directly connected with Oceanica.

OCEANIA

This region is not rich in brachiopods and has 3 restricted but widely distributed genera. From the Austral region there have migrated into the Australia-New Zealand area Kraussina, Magellania, and Terebratella, but they are not known north of these land masses. Common throughout this island realm are the restricted genera Lingula (also sparingly present in the Indian Ocean), Frenulina, and Basiliola (restricted to Hawaii); the two first named genera extend their range to Japan.

GONDWANA

The remaining brachiopod genera, 14 in number, appear to owe their dispersion in the main to the former but now much broken shore of ancient Gondwana. The present Mediterranean is the remainder of the ancient and far more extensive Tethys, always more or less in connection with the North Atlantic (= Poseidon) and in early Tertiary time communicating freely with the Indian Ocean. Tethys is the boundary of the northeastern area of Gondwana, and the shore thence continued westward across the Atlantic from northwestern Africa, possibly by way of the Canary and Cape Verde Islands, to Venezuela and the Antillean region. Western Gondwana, however, was being severed by Poseidon and Nereis (North and South Atlantic) during the Cretaceous, and their union into the present Atlantic certainly took place during the early Eocene. During the Tertiary previous to the Upper Miocene there was also an open seaway between the Caribbean-Panama region, so that the northern Gondwana faunas could readily continue their march south along the western side of South America into the Antarctic realm, whose waters were then much warmer than they are now. Of these Gondwana brachiopods but few, however, got into the North Pacific. To make this immensely long and very important migration route clearer, it will be necessary to present the geographical range of the genera of this realm in detail.

Restricted to the Mediterranean-Cape Verde and Portugal-England regions there are the 3 genera Gwynia, Megathyris, and Mühlfeldtia

(may have representation in South Australia in *Megerlia* (?) *willemoesi*). In common with this region and the northwestern side of Gondwana or the Antillean-Floridian and Caribbean area are the genera *Cistella*, *Eucalathis* (1 species in the Fiji region), *Platidia* (has spread to Lower California, but not to South America), and *Thecidium*.

There are 9 other genera that must be considered in detail:

Glottidia.—This genus had its origin apparently in the Antillean region, spread north as far as North California, south to Martinique, and in the Pacific north to southern California and south to Peru. The genus is known in the Pliocene of California, and the spreading probably took place previous to the upper Miocene when the Panama land bridge, between North and South America, was established. *Glottidia* seems to be not older than the Tertiary.

Discinisca.—The genus is most abundant off the South American Pacific, has spread north to the Gulf of California, and is sparingly present in the Antillean region. A single species occurs from Singapore to Japan. As the genus probably dates from the late Mesozoic we may have here local continuance of a formerly much wider, now much broken and discontinuous distribution. On the other hand, the present dispersal may be due to larval transportation, for the larvæ of the deep-sea *Pelagodiscus* (formerly called *Discinisca*) have been taken in the drag net very far from land and are known to live in the free and floating condition for nearly a month.

Crania.—This genus is very common throughout the Paleozoic and Mesozoic faunas of the northern hemisphere, and it is therefore probably safe to assume that it originated here. In any event *Crania* is today most abundant in northern oceans, where there are 4 species. In the southern hemisphere there are 3 forms, 1 off southeastern Australia, 1 in Antarctica, and 1 off western Patagonia. Its distribution seems to agree closely with that of *Terebratulina*.

Cryptopora has a greatly discontinuous distribution and may not owe its present occurrences to Gondwana. It was originally described (*C. gnomon*) from the north Atlantic, and is now known to be almost universal throughout the deep waters of this ocean from Davis Strait and Tromsø to off Morocco, the Azores, and the Canaries. The other form (*C. brazieri*) occurs in shallow water off New South Wales.

Terebratulina probably originated in the northern hemisphere and is known fossil since the Jurassic. Its greatest present specific development is about Japan, where 6 forms are known. In the northern hemisphere are living 11 species, against 3 in the southern hemisphere. In other words, the genus is common to almost all shores in the northern hemi-

sphere, and its other main distribution is along the north shore of Gondwana (2 species in the western Mediterranean), extending as far as the Antilles (1) on the west (none are present off western South America), on the east into the Indian Ocean (1), and probably across Asia in former Tethys to the Pacific. Along the southern side of Gondwana the genus probably spread along the shores of the Indian Ocean to south-eastern Australia (1) and to the Cape of Good Hope (2). In the vast area of the Atlantic Ocean between Africa and South America there is but a single species, and this is the Antillean *T. caillieti*, occurring off Brazil at Pernambuco and Rio de Janeiro and as a relict in the mid-oceanic island Ascension.

Dyscolia wyvillii probably originated in ancient Tethys, where its ancestor, *D. guiscardiana*, is found in the Pliocene of Sicily. The living species is rare at the Maldives in the Indian Ocean, but is more common in the Atlantic off Spain, Portugal, northwestern Africa, and the Cape Verde Islands. As a relict it occurs off the Lesser Antilles. The other form, *D. crossii*, originally described from the east shore of Japan, is also reported by Fischer and Ehlert from Punta Arenas, in the Magellan Straits, and from New Year Sound. By combining the distribution of these two species we see that the genus has extended itself along the northern, western, and northeastern shores of Gondwana, and from the Austral waters to Japan, probably by way of Oceanica. While the genus is known only since the Pliocene, its large size and primitive loop makes it probable that its origin goes back to the Cretaceous. Its nearest relative is Terebratulina, which had its origin in the Jurassic.

Liothyrina.—This genus has the greatest number of species of all living genera (14), even more than Terebratulina. Its geographical distribution has recently been worked out by Blochmann (1908, plate 40) with the greatest care. The center of distribution was the north shore of Gondwana (Atlantic-Poseidon), where (western Mediterranean) at least 5 species are living. From the Antillean region (2) the genus extends down the west side of South America (3 species, 1 *L. uva*), and thence eastward into the Antarctic region to the Falklands, South Georgia, south of Africa, Kerguelens, Saint Paul (south Indian Ocean), and Kaiser Wilhelm Land to southeastern Australia. From the Australian region it probably spread northwest through Oceanica to Japan, where 2 species occur, but no linking forms are known to live now in the intermediate region. From the Mediterranean region the genus spread less abundantly northward along western Europe (2) into the Arctic region (1) of Jan Mayen, Iceland, and the east coast of Greenland. None are on either side of the North American continent. From the Magellan region

L. uva (widely distributed from Tehuantepec to Cape Horn and South Georgia) has crept north in the Atlantic as far as Buenos Aires, and with the breaking down of Gondwana, *L. cubensis*, an Antillean species here of wide distribution, has maintained itself with modification on Ascension as a relict, but is now recognizable, according to Blochmann, as a distinct geographic variant. Another associated relict here is *Terebratulina caileti*. In regard to the remarkable distribution of the 3 closely allied forms of *Liothyryna* (*L. sphenoidea* in Lusitanian region, *L. cubensis* in Antillean, and the Ascension unnamed form), Blochmann (1906, page 701) states the following: "The 3 forms are the descendants of one that was bound to the shores of the central Mediterranean, which was extant up to Tertiary time, and since then the stock has been broken into the 3 discontinuous areas. Ascension we must regard as a part of the north shore of the land-bridge that once united Africa with South America."

Chlidonophora.—This deep-sea genus had its origin along the north shore of Gondwana, and *C. incerta* is found off Havana to the northwest of Trinidad and in the equatorial mid-Atlantic. The other form occurs in the Indian Ocean off the Maldives and Laccadives. The spread was through ancient Tethys.

Macandrevia.—Its most typical development (*M. cranium*) is now off the coast of Norway, spreading thence to North Cape and Greenland, east coast of North America at great depths, and south off Europe into the Mediterranean area. *M. tenera* occurs in Davis Strait, but there is no representation now in the Antillean region. In the Pacific, in the Gulf of Panama, 3 species occur, and 2 of these are also known in the deeps off Chile and Peru. Recently Blochmann has described a final species from the Antarctic Kaiser Wilhelm Land.

EQUATORIAL ATLANTIC

There is a great dearth of brachiopods in the equatorial Atlantic between 10 degrees north and 30 degrees south latitude. But a single shallow-water species is restricted to this great region. This is *Discina striata*, found in the littoral at Cape Palmas, Africa, and may be of Mediterranean origin. The few other brachiopods of this region are either northern relicts (2) of broken Gondwana, or deep-sea migrants (2), or shallow-water migrants from the Antillean regions (2). On Ascension, in mid-Atlantic, are found the relicts *Liothyryna cubensis*? (now changed into another form according to Blochmann) and *Terebratulina caileti* (also off northern Brazil). The only other northern migrant along the eastern shore of South America is the Antillean *Cis-*

tella barrettiana, dredged off Rio de Janeiro. Of deep-sea migrants into the tropical Atlantic are *Chlidonophora incerta* (on the equator in mid-ocean) and *Pelagodiscus atlanticus* (1 degree north, 24 degrees west). Mediterranean relicts, as *Liothyryna vitrea* and *Dyscolia wyvilii*, occur to the north of the region designated—that is, on the Cape Verde Islands.

From the Antarctic region have come the 3 migrants *Liothyryna uva* (north to Rio de Janeiro), *L. wyvilii* (Falklands), and the very characteristic boreal *Bouchardia rosea* at Rio de Janeiro.

In other words, along the shores of eastern South America (5) and off the western coast of Africa (1) are found but 6 species, there being 2 others in the deep sea and 4 relicts on oceanic islands, one of which occurs also off Brazil.

This survey of brachiopod distribution shows clearly not only the former existence of equatorial Gondwana across the Atlantic, but as well that its vanished Atlantic bridge still controls the distribution of living forms. We see that the genera of the northern Atlantic (Poseidon) distributed themselves in one direction, more or less widely throughout the northern hemisphere and in another pathway eastward into the Indian Ocean by way of the northern shore of Gondwana, but the main drift was far more decidedly westward along the same land by way of the Antillean region into the Pacific, and thence in the main down the west coast of South America into the Antarctic realm. Gondwana appears to have existed until middle Eocene times; the deciding land barrier between the fauna of the northern and southern hemispheres and the inter-hemisphere shallow-water genera followed either its shores or those of Oceanica and the northern Pacific bounding lands. What is true regarding the dispersion of brachiopods will probably be found essentially similar for other groups of animals with short non-feeding larval stages and inhabiting equatorial waters.

STRATIGRAPHIC SIGNIFICANCE OF OSTRACODA¹

BY R. S. BASSLER

The recent bivalved crustaceans falling under the order Ostracoda are world-wide in their distribution both in fresh and salt waters. Not only are many of the species properly termed cosmopolitan, but they are also apparently unlimited bathymetrically. Today we find them swimming at the surface or creeping over the bottom in great colonies, and after the

¹ Manuscript received by the Secretary of the Society May 23, 1911.

death of the animal their shells are scattered far and wide, both on the land and in the water. Many of us in our field work have no doubt come across small pools, sometimes a foot or less in diameter, swarming with darting fresh-water ostracods or water fleas. In such instances, as evaporation proceeds, the pool will become a fairly solid mass of ostracods, and finally, when the water has disappeared entirely, their dead shells will be scattered by the winds as dust, sometimes to considerable distances. Fresh-water Ostracoda are therefore a factor in continental deposits. In the sea a similar wide dispersal, independent of the animal's life history, depends on the waves and currents, which bear the dead shells far from their habitat in life and scatter them broadcast, so that their final resting place may be in the deep-sea ooze or in the shallow littoral deposits.

Most of the modern as well as ancient Ostracoda are of microscopic size, and for this reason, even though in individual development they probably exceed almost every other class, they must always remain an inconspicuous element of any fauna. Another and more serious difficulty, especially in the study of the fossil forms, lies in the simplicity of shell structure found in some of the families. Among the recent faunules, species and even genera are established on anatomical characters, the shell being practically disregarded. It is a fact that several distinct genera have shells with essentially the same outline and surface characters. The difficulty, if not impossibility, of distinguishing such genera among fossil forms is obvious. For example, *Bythocypris cylindrica*, an abundant fossil in practically all of the Middle and Upper Ordovician formations, is closely differentiated from associated Cypridæ, yet the name possibly includes a number of distinct species. In outline and general structure its shell can be duplicated in several genera of living forms. On account of lack of character, this great group, which was more or less abundantly developed from the Ordovician on to the present, will not be mentioned in the further discussion.

From the foregoing remarks the bearing of the Ostracoda on paleogeography would seem to be insignificant had the class always possessed the characteristics shown by many of the recent forms. However, judging especially from their associates in the ancient continental seas, most of the Paleozoic representatives were much more limited in their habitat. Further, many of the Ordovician and Silurian species, particularly those comprised in the family Leperditiiidæ, are not such inconspicuous fossils. While the average recent ostracod seldom exceeds a millimeter in length, certain Silurian *Leperditias*, the giants of the order, are 30 to 40 millimeters long. Again, there are hosts of forms like the Beyrichiidæ of

Paleozoic rocks and the Cytheridæ of Mesozoic and Recent times that are marked by great diversity of surface pattern, which lends itself to accuracy of specific discrimination.

Taking up the Paleozoic Ostracoda, we find that they have a distinct advantage over practically all other organisms in their occurrence in all kinds of rocks. While most abundant in limy sediments, they are also exceedingly common in highly siliceous strata in all kinds of shales, and even in relatively coarse, beach-worn sandstone. They are thus ubiquitous in their distribution and indiscriminate in the kind of water and sediments.

Many species supposed to be Ostracoda have been described from Cambrian rocks, but recent unpublished studies show that all of these are bivalved phyllopods. The first unquestionable Ostracoda, a few species of *Leperditia*, are found in the early Canadian rocks of west Tennessee, Missouri, Arkansas, and Oklahoma. Since they are wholly unknown in rocks of essentially the same age in the Appalachian region, it is inferred that the class, like many other groups of Paleozoic organisms, originated in or south of the Gulf of Mexico. It is only in the later stages of this period that the class attained representation in the more northern region. In the Ordovician a great expansion of the class occurred. The Leperditiidæ continue in full or increased strength, while the main families of Paleozoic time are introduced.

During the Middle Ordovician there seems to have been a shifting of the Ostracoda from the southern seas to the northern. This was accompanied by a considerable change in type. Thus, while the Ostracoda of the Stones River and the succeeding Black River faunas, which are of southern origin, consist almost entirely of Leperditiidæ, the next succeeding deposits from the Baltic region and the northern areas of North America contain very few or none of these, but instead a considerable development of the more primitive types of Beyrichiidæ. Further, all types of Ostracoda are rare, except a few like the cosmopolitan genus *Eurychilina*, in the rocks of Trenton age in the Mississippi and Appalachian valleys. The later Ordovician rocks contain a great influx of species quite similar to the late Black River forms as developed in the Baltic region of Europe and in America north of Missouri. During this time, then, the supply seems to have been derived by emigration from the northern seas rather than directly from the southern.

The earliest Silurian, Richmond formation, has the same generic representation; indeed, this continues with little change through the middle Silurian.

The later Silurian is marked by a very decided development of the genus *Beyrichia* and its related type, *Klædenia*. A striking feature respecting these genera is that whereas the true species of *Beyrichia* are exceedingly rare in all American deposits of similar ages, on the other hand *Klædenia* occurs on both sides of the Atlantic, while another genus, *Klædenella*, obtained extraordinary development in the Silurian rocks of the Appalachian Valley and is almost unknown in Europe. True Leperditiiidæ continue throughout the Silurian.

With the inauguration of the Devonian the general aspect of the Ostracoda changes markedly. True Leperditiiidæ have practically disappeared, only a few stragglers occurring in the lower beds of the Helderbergian. The Beyrichiidæ have modified into new generic groups with a quite different aspect. The hitherto poorly represented genera, like *Kirkbya*, *Octonaria*, *Thlipsura*, etcetera, now make up a considerable proportion of the total number. The general aspect of this ostracod fauna was not materially changed until the close of the Paleozoic. In abundance and variety American Devonian ostracods are in contrast with those of Europe because the latter are so poorly developed. It appears that the area of development and dispersal was again shifted back to South Atlantic waters. In fact, it seems that they were almost confined to these waters until well toward the close of the Paleozoic. In the Pennsylvanian a number of types not hitherto seen are introduced, the notched cypridinoids, primitive Cytheriidæ, and numerous cytherelloids. At this time a host of fresh-water forms are introduced—the first known. By this time the marine Ostracoda have become so cosmopolitan that the locus of their development can no longer be traced. Although still of aid in broad correlation, their value in detailed correlation and in the discrimination of paleogeographic provinces has been almost entirely lost. In succeeding time the fresh-water forms become more and more abundant. They are frequently found in the Red Beds of the West, and layers are often almost made up of them in the land deposits of the Cretaceous and Tertiary. While a few can be determined as land forms, many others are so similar to the marine Cypridæ that on their own evidence it would be almost impossible to decide that they are actually land forms and not marine.

From the foregoing it will be seen that while the Ostracoda are of very considerable value in stratigraphic correlation and throw light on paleogeographic problems up to the Pennsylvanian, their value in this respect seems to be much diminished in later times.

RELATION OF THE PALEOZOIC ARTHROPODS TO THE STRAND-LINE¹

BY JOHN M. CLARKE

None of the Crustacea have shown a wider distribution than the trilobites. As to these trilobites there seems to be little in their mode of life to throw light on oscillations of the strand. They were not very sensitive organisms. Their primitive composition accounts for that in no small measure, so they adapted themselves to bathymetric differences of some considerable degree. We find their moults in the sands and the shales and the limestones of the Paleozoic, and doubtless some part of these have been washed out of their proper depth into the debris of the bottom, but their jointed skins are found as well in all these deposits, and we know they lived in shallow sands and deeper muds within perfectly easy reach of land waste. Their ready adaptability and their locomotive powers carried them easily over differences in sediment and depth, so in the habitude of these creatures there is really little to serve as a guide to geographic changes. In their anatomy there is more. I have long been impressed with the possibility that the relative development of the eye in these and other crustaceans, whether simple or compound, might afford some clue to the bathymetric conditions governing these animals. With our old knowledge it has seemed that the highly developed compound lenses in all the later trilobites, eurypterids, and in all the early shrimps and crabs must be a definite response to the amount of light received in their habitats; that the vaguely developed visual area in many of the Cambric trilobites, sensitive to light only in a general way along streaks on the head, should express a depth of water corresponding to a minimum of light received, but there were incongruities in these conceptions long before we knew the reasons for them. *Æglina*, with its enormous compound eyes, among its lensless associates of the Cambric, the undeniable evidence of shallow-water condition, in which the unspecialized eyes of the Cambric trilobites were produced, the counter-evidence of the highly developed ommatidia in the Phacopes and Dalmanites of the deeper waters of Siluric and Devonian, Walcott's demonstration that the visual areas in *Olenellus* bear lenses—these and similar incongruous conditions in the present deep sea from the *Cystosoma*, with its tremendous ocular development to the blind crab *Willemossia*, go to show that the de-

¹ Manuscript received by the Secretary of the Society May 27, 1911.

velopment of the visual organ is partly a matter of growth and decline and in a large part an adaptation. The pigment about the ommatidia of a compound eye can by its readjustment adapt the organ either to the dusk or the brightness, and an elaborate compound eye thus fits all depths, shallow or great. I suggested last year that conditions of long isolation are sometimes, more often than we think, indicated by the resumption of primitive ornaments in the trilobite integument at a stage where in the normal progress of the race the creatures have burst into their climax of decoration, as in the trilobites of the austral Devonian, where even the sutural spines of the Cambrian reappear in conjunction with the climacteric decoration of the race appropriate to the Devonian period. Here, too, isolation shows its effects in the development of expressions of lobal coalescence and pygidial decoration not elsewhere known. These characters in morphology are positive factors in the determination of the limitations of the strand, and morphology does in its total expression prove the most dependable index of geographic differences. The eurypterids, in their life history and in their climax, are far more sensitive to geographic changes. The few early eurypterids we know were doubtless marine, and the creatures gradually acquired the brackish-water habit of their climax, which seems to have eventually changed to a fresh-water life. The value of these creatures as indexes of geography at any one time in the earth's history is therefore quite evident.



Proceedings of the Paleontological Society

PROCEEDINGS OF THE NINTH ANNUAL MEETING OF THE
PALEONTOLOGICAL SOCIETY, HELD AT PITTSBURGH,
PENNSYLVANIA, DECEMBER 31, 1917, AND JANUARY 1
AND 2, 1918.

R. S. BASSLER, SECRETARY

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R. S. BASSLER, *Secretary*

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SESSION OF MONDAY, DECEMBER 31

President Merriam called the Society to order in general session at 10 a. m., Monday, December 31, in Rehearsal Hall of the Carnegie Museum. Doctor Holland welcomed the Society to Pittsburgh in a patriotic speech, which was appreciated and warmly applauded by the members. Following Doctor Holland, President Merriam opened the exercises with an inspiring address, the keynote of which was our duty to science at the present dark moment.

The first matter of business before the Society was the report of the Council, which was then presented.

REPORT OF THE COUNCIL

To the Paleontological Society, in ninth annual meeting assembled:

This year's Council has held two regular meetings for the transaction of the Society's business—one at the adjournment of the meeting at Albany, December 29, and the second just before the present session. As usual, most of the business has been conducted by correspondence. The following reports of officers give a résumé of the administration for the ninth year of the Society:

SECRETARY'S REPORT

To the Council of the Paleontological Society:

Meetings.—The proceedings of the eighth annual meeting of the Society, held at Albany, New York, December 27-29, 1916, have been printed in volume 28, pages 189-234, of the Bulletin of the Geological Society of America, published on March 31, 1917. On account of the great delay in publication due to war conditions, only two numbers of the four published annually as the Bulletin of the Geological Society of America have been issued up to the present date, and the proceedings is the only one of our Society's publications that has so far been printed. Number four of this Bulletin, now in press, contains three articles by members of our Society. However, a second publication—an extensive paper by Doctor Grabau, published at the end of 1916—was distributed during the present year, so that while the number of papers has been smaller the number of printed pages has been about as usual.

The announcement that the ninth annual meeting of the Society would occur at Pittsburgh, Pennsylvania, beginning December 31, 1917, at the invitation of the Carnegie Museum, through the Director, Doctor William J. Holland, was forwarded to the members on March 26, 1917, with the Council's proposed nominations for officers.

At the meeting of the Council just concluded, it was voted that in view of the increased membership and business of the Society, the Secretary was empowered to expend not more than \$25 per year for necessary clerical assistance.

Membership.—During the year the Society has lost by death Prof. Henry M. Seely, who died May 4, 1917, and Prof. William Bullock Clark, who died early in July, 1917. Professor Seely was one of our oldest members and had been Professor of Natural History at Middlebury College, Middlebury, Vermont, since 1861. His best known geologic work was on the stratigraphy and paleontology of the Beekmantown and Chazy

formations of the Champlain Valley. Professor Clark was in the prime of life, and his passing is a great blow to our science. His works on the Atlantic Coastal Plain, and especially on the geology and paleontology of Maryland, are too well known to be mentioned in detail.

Eight new members were elected to the Society at the eighth annual meeting, making the enrollment at the end of 1916, 184. Nine new members are under consideration for this meeting, so that at the present rate the Society will pass the 200 mark within a year. Five members of our Society were elected to Fellowship in the Geological Society of America at the election just concluded.

Pacific Coast Section.—The eighth annual meeting of the Pacific Coast Section of the Paleontological Society was held at Stanford University on April 6 and 7, 1917, the Society participating in the second annual meeting of the Pacific Division of the American Association for the Advancement of Science. On April 6 the Society met in joint session with the Geological Society and the Seismological Society, at which time Prof. John C. Merriam delivered an address on preparedness. This joint session adjourned at the conclusion of Professor Merriam's address, and the Paleontological Society was called to order in separate session by Dr. J. P. Buwalda at 3.15 o'clock, in room 360, Mineralogy Building.

The following officers were elected for the ensuing year:

President, BRUCE L. CLARK.

Vice-President, CHESTER STOCK.

Secretary-Treasurer, CHESTER STOCK.

Nineteen papers, dealing with both the Vertebrate and Invertebrate Paleontology and Stratigraphy of the West Coast especially, were read at this meeting. Twenty-two members and visitors were present. The minutes of this section are printed on pages 160 to 166 of this Bulletin.

Respectfully submitted,

R. S. BASSLER,
Secretary.

WASHINGTON, D. C., December 31, 1917.

TREASURER'S REPORT

To the Council of the Paleontological Society:

The Treasurer begs to submit the following report of the finances of the Society for the fiscal year ending December 19, 1917:

RECEIPTS

Cash on hand December 26, 1916.....	\$481.65
Membership fees (1916).....	12.00
Membership fees (1917).....	243.10
Interest, Connecticut Savings Bank.....	13.86
	<hr/> \$750.61

EXPENDITURES

Treasurer's office:

Postage	\$4.00
Stationery and printing.....	9.75
	<hr/> \$13.75

Secretary's office:

Secretary's allowance.....	\$50.00
Expenses	47.49
	<hr/> 97.49
	<hr/> 111.24

Balance on hand December 19, 1917..... \$639.37

Net increase in funds..... \$157.72

Outstanding dues (1916), 4.....	\$12.00
Outstanding dues (1917), 9.....	27.00
	<hr/> 39.00

Respectfully submitted,

RICHARD S. LULL,
Treasurer.

NEW HAVEN, CONNECTICUT, *December 19, 1917.*

APPOINTMENT OF AUDITING COMMITTEE

Following the reading of the Treasurer's report, on vote of the Society, Burnett Smith and W. A. Parks were appointed a committee to audit these accounts.

ELECTION OF OFFICERS AND MEMBERS

The announcement of the election of officers for 1918 and of new members was the next matter of business. The results of the ballots were as follows:

OFFICERS FOR 1918

President:

F. H. KNOWLTON, Washington, D. C.

First Vice-President:

ARTHUR HOLLICK, New York City

Second Vice-President:

L. W. STEPHENSON, Washington, D. C.

Third Vice-President:

F. B. LOOMIS, Amherst, Mass.

Secretary:

R. S. BASSLER, Washington, D. C.

Treasurer:

R. S. LULL, New Haven, Conn.

Editor:

C. R. EASTMAN, New York City

NEW MEMBERS

F. E. CLEMENTS, Carnegie Institution, Washington, D. C.

LEE RAYMOND DICE, University of Montana, Missoula, Mont.

CHILDS FRICK, Santa Barbara, Cal.

EUGENE SCHOFIELD HEATH, Botany Hall, University of California, Berkeley, Cal.

REMINGTON KELLOGG, 2212 A Union, Berkeley, Cal.

WAYNE FREDERICK LOEL, Department of Geology and Mining, Stanford University, Palo Alto, Cal.

IDA CARTER OLDROYD, College Terrace, Palo Alto, Cal.

CARROLL MARSHALL WAGNER, 2604 Etna Street, Berkeley, Cal.

ELECTION OF NEW MEMBERS

The President then reported that the Council had acted favorably on the request of William F. E. Gurley, of Walker Museum, University of Chicago, and William A. Price, of West Virginia University, Morgantown, West Virginia, both members of the Geological Society of America, who had signified the wish to become members of the Paleontological Society. He also stated that the following nomination for membership, received too late for the printed ballot, was favored by the Council:

Mrs. EULA D. McEWAN, A. B. (1913), A. M. (1914) Indiana University, Scientific Aid in Paleontology, U. S. National Museum. Engaged in study of fossil invertebrates. Proposed by E. O. Ulrich and R. S. Bassler.

On motion by Mr. David White and the unanimous vote of the members, the Secretary was instructed to cast the ballot of the Society for election to membership of Messrs. Gurley and Price and Mrs. McEwan.

PRESENTATION OF PAPERS ON PALEONTOLOGY AND STRATIGRAPHY

The first paper on the program, dealing with the stratigraphy and paleontology of the Paleozoic rocks on the Piedmont plateau, was illustrated by lantern slides and was discussed by Messrs. Grabau and Merriam, with replies by the author.

PALEOZOIC DEPOSITS AND FOSSILS ON THE PIEDMONT OF MARYLAND AND VIRGINIA

BY R. S. BASSLER

(Abstract)

The western part of the Piedmont plateau in Maryland and Virginia contains areas of early Paleozoic limestone infolded in the Precambrian crystallines and overlaid in part by the Triassic (Newark) series. These limestones outcrop at one point next to the early Cambrian Harpers shale, and it has hitherto been believed that they represented the Shenandoah limestones of the Appalachian Valley, comprising strata from early Cambrian to Middle Ordovician time. Detailed mapping of this area and the discovery of fossils has shown that this Piedmont limestone consists of a lower massive limestone division with Lower Beekmantown fossils separated by a well marked disconformity from an upper thin bedded dark-blue limestone with a Chazy fauna. The Lower Beekmantown division can be correlated directly with strata in the Appalachian Valley, but the Chazy portion has no representation there.

There was then presented a study of an interesting problem in Devonian stratigraphy by the author, illustrated with diagrams, which brought forth discussion from several members of the Society.

SIGNIFICANCE OF THE SHERBURNE BAR IN THE UPPER DEVONIC STRATIGRAPHY

BY AMADEUS W. GRABAU

(Abstract)

The original Sherburne sandstone of Vanuxem formed a bar which extended from the old-land of Atlantica on the north to the mouth of the Devonian Romney River on the south. During its maximum development, shortly after the close of the Hamilton period, it was about ten miles wide and formed an effective barrier between the Atlantic region which carried the typical Hamilton fauna and western New York and the region beyond. In this area a remnant of the Hamilton fauna, cut off from intercrossing with the main stock, developed into the early Ithaca, or lower Portage fauna, to which were added migrants from the Traverse survivors of the west. Meanwhile the pure Hamilton, or Tropidoleptus, fauna continued in the embayment east of the bar, remaining in constant communication with the center of distribution of this fauna in the Atlantic. In the Far West the Naples fauna made its entrance.

so that three faunas existed simultaneously in New York—the Naples in the west, the Lower Portage, or pure Ithaca, in the center, and the Hamilton in the east. Submergence of the bar permitted an intermingling of the Hamilton and pure Ithaca faunas, and so produced the mixed fauna commonly taken as typical (but not the pure) Ithaca fauna. These facts are demonstrated by showing the percentages of each of the faunal units found in the successive sections from west to east.

Professor Moore, a visiting Fellow of the Geological Society of America, then gave an interesting account of algal limestones of the Far North. His paper was illustrated by lantern slides and was discussed by Messrs. White, Merriam, Grabau, and Bassler.

ALGAL LIMESTONE ON THE BELCHER ISLANDS, HUDSON BAY

BY E. S. MOORE¹

(Abstract)

The Belcher Islands are situated off the east coast of Hudson Bay and consist of rocks similar in many respects to those formed on the coast and which have been described by Leith and Low. The islands were little known until recently, when considerable areas of jasper were discovered on them. Associated with this iron formation there is a remarkable band of concretionary limestone over 400 feet thick and consisting of spherical to subspherical balls varying from about an inch to 15 inches in diameter. These were at first regarded as cryptozoons, but their spherical form and the almost total absence of the crenulated character of the cryptozoons seem to separate them, at least from *Cryptozoon proliferum*. They resemble more strongly some of the recent algal concretions found in lakes and streams and described by Clarke, Roddy, and others. A smaller type is similar in some respects to Walcott's *Collenia frequens*.

In the associated iron formation there are numerous granules of calcite, silica, and iron silicate. The two former bear a close resemblance to certain granules which occur in the Lower Paleozoic limestones of central Pennsylvania and which grade without break into distinct oolites. The occurrence of these concretions, both large and small, and their associations point strongly to organic origin of the limestone and iron deposits, and it indicates further that these rocks are either not Precambrian, as they have been supposed to be, or that an abundance of low types of life existed in the Hudson Bay basin in Precambrian time.

At 12.30 p. m. the Society adjourned for luncheon, convening again at 2 p. m. for the reading of the paleobotanic papers of the symposium. Although the absence of several of the authors prevented a full discussion of their papers, which were read by other members of the Society, a number of interesting and instructive points were brought out in the remarks by Messrs. Matthew, Vaughan, White, Merriam, Ami, Osborn, and others.

¹ Introduced by R. S. Bassler.

SYMPOSIUM ON PROBLEMS IN HISTORY OF FAUNAL AND FLORAL RELATIONSHIPS IN THE ANTILLEAN-ISTHMIAN REGION AND THEIR BEARING ON BIOLOGIC RELATIONSHIPS OF NORTH AND SOUTH AMERICA

RELATIONS BETWEEN THE PALEOZOIC FLORAS OF NORTH AND SOUTH AMERICA

BY DAVID WHITE

RELATIONS BETWEEN THE MESOZOIC FLORAS OF NORTH AND SOUTH AMERICA

BY F. H. KNOWLTON

PALEO GEOGRAPHIC SIGNIFICANCE OF THE CENOZOIC FLORAS OF EQUATORIAL AMERICA AND THE ADJACENT REGIONS

BY EDWARD W. BERRY

BEARING OF THE DISTRIBUTION OF THE EXISTING FLORA OF CENTRAL AMERICA AND THE ANTILLES ON FORMER LAND CONNECTIONS

BY WILLIAM TRELEASE

After the conclusion of the first part of the symposium, there was sufficient time before adjournment for the day for the presentation of the first paper in the list of those dealing with the invertebrate paleontology of Central America and the West Indies. This paper on the Paleozoic history was presented by the author and was illustrated by lantern slides of paleogeographic maps. Both the papers and the maps called forth such criticism and comments from Miss O'Connell and Messrs. Grabau, Matthew, Vaughan, and others that new data were added to this somewhat doubtful portion of Central American history.

PALEOZOIC HISTORY OF CENTRAL AMERICA AND THE WEST INDIES

BY R. S. BASSLER

At 5.30 p. m. the Society adjourned, meeting again at 8 p. m. at the University Club, to hear the address of the retiring President.

PRESIDENTIAL ADDRESS BY J. C. MERRIAM

AN OUTLINE OF PROGRESS IN PALEONTOLOGIC RESEARCH ON THE PACIFIC COAST

Doctor Merriam's account of the progress of all three branches of paleontology on the west coast was followed with much interest and attention by the fifty or more members and visitors who were present.

SMOKER TO THE SOCIETY

The presidential address was followed by a smoker to the Society as guests of Doctor Holland, Director of the Carnegie Museum. After refreshments had been served and conversation had continued for an hour, Doctor Holland, the host of the evening, called the Society to order and introduced one member after another for impromptu talks and reminiscences. The good stories related by Doctors Holland, Osborn, Williston, Ami, and Grabau, of American and foreign paleontologists, were especially enjoyed. The Society also had the pleasure of listening to addresses by the Chancellor of the University of Pittsburgh, members of the Board of Trustees of the Carnegie Museum, and other guests, and from several of the Fellows of the Geological Society of America. As the hour of 12 approached, Doctor Holland, in a patriotic address, emphasized the duty of science to the nation, and asked us to mark the passing of the old year with a pledge to our country. As the whistles of the great steel mills along the three rivers of Pittsburgh, the armorer of the nation, announced the birth of the New Year, we arose and pledged ourselves anew by the singing of "America."

SESSION OF TUESDAY, JANUARY 1

Tuesday morning, at 10 o'clock, the members met in the hall of vertebrate paleontology of the Museum and were shown all the choice specimens of the exhibit by Doctor Holland, who pointed out the most striking and interesting features in each. Time was lacking for a complete tour of the Museum, so Doctor Holland then guided us through the laboratories of vertebrate paleontology, where, with the magnificent specimens before us, he presented the following paper:

SOME OBSERVATIONS ON THE OSTEOLOGY OF DIPLODOCUS

BY WILLIAM J. HOLLAND

Questions and remarks by Doctors Osborn, Williston, and Matthews, with replies by Doctor Holland, added to this interesting discussion and gave the members an insight into the great explorations by the Carnegie Museum and its richness in vertebrate remains. The recently acquired material of *Diplodocus* in the possession of the Carnegie Museum, including a perfect skull, in which even the sclerotic coat of the left eye-ball had been petrified, was the especial subject of Doctor Holland's paper,

although he touched on and disposed of the recent criticisms of Rev. H. W. Hutchinson.

At 11.30 the Society commenced again in general session to continue the reading of papers, with Doctor Merriam presiding. The chairman announced that, in order to give variety to the program, papers from the three branches of paleontology would be interspersed. The first paper was a paleobotanic one, illustrated with specimens. Discussed by Messrs. Holland, Williston, Merriam, and Vaughan.

CRITICAL STUDY OF FOSSIL LEAVES FROM THE DAKOTA SANDSTONE

BY E. M. GRESS¹

(Abstract)

The study has been based on a collection consisting of about 100 specimens. About 80 of these are from a large collection of fossils purchased from Baron Ernst de Bayet, of Brussels, a few years ago, the remainder from the United States National Museum by exchange. The Bayet collection comes from Ellsworth County, Kansas; the others from different parts of Kansas and Nebraska.

A few of the specimens had already been identified, some by Leo Lesquereux; others by an unknown person. Most of them bore no record of identification. All specimens have been carefully examined, and those bearing no labels have been identified, while those already identified have been verified.

The collection is represented by about 65 species and 25 genera, among which the most common are the following: *Aralla*, *Betulites*, *Ficus*, *Magnolia*, *Populus*, *Protophyllum*, *Sassafras*, *Sterculia*, and *Viburnum*.

In our study of the fossils we have included a brief review of the history, location, and correlation of the "Dakota Formation," with a careful description of each species and citations of available references. A critical study and comparison of each specimen with other described and figured species and with type forms has been made.

Professor Osborn then presented his interesting papers on vertebrate paleontology, both of which were illustrated by lantern slides. In the discussion of these papers Messrs. Holland, Merriam, Peterson, Granger, and Matthew took part.

OBSERVATIONS ON THE SKELETONS OF MOROPUS COOKI IN THE AMERICAN MUSEUM

BY HENRY FAIRFIELD OSBORN

(Abstract)

Moropus is the largest and most distinctive mammal of Lower Miocene time in western North America, and has attracted a great deal of attention from

¹ Introduced by O. E. Jennings.

paleontologists because of the long period of uncertainty as to its highly unique structure and adaptations and its great rarity as a fossil, the latter due probably to its forest-frequenting habits.

With its companions, the giant elothere pig, known as *Dinohyus*, and the diminutive pair-horned rhinoceros, *Diceratherium*, its remains have since 1882 been found in profusion in the Agate Spring Quarry of Sioux County, western Nebraska. This quarry lies in the upper portion of the Lower Harrison horizon of Hatcher and was discovered by Mr. James H. Cook, of Agate, in the year 1877. Prof. Erwin H. Barbour collected the first actual *Moropus* material from the Agate Springs quarries in July, 1892. Mr. Harold Cook made a considerable excavation in 1904, but it was not until 1908 that the specific name *Moropus cooki* was given by Professor Barbour¹ (January 26, 1908), thus identifying the animal generically with Marsh's type of *Moropus* from a somewhat more recent deposit.² In the meantime very extensive excavation and exploration was carried on by the Carnegie Museum for *Moropus*, *Dinohyus*, and *Diceratherium* remains, and after preliminary description the *Moropus* skeletons were described in detail in an important memoir in 1909.³

These carefully conducted excavations by Mr. O. A. Peterson, under Dr. W. J. Holland's direction, proved that the Agate Springs Quarry is the most remarkable deposit of mammalian remains of Tertiary age that has ever been found in any part of the world. Its only rival in the quantity of material preserved is the mid-Pleistocene deposit of Rancho La Brea, near Los Angeles, southern California.

In 1911, through the courtesy of Messrs. James H. Cook and Harold Cook and with their highly intelligent cooperation, the American Museum excavations began under the direction of Mr. Albert Thomson, assisted by Mr. Charles Barner, and continued through 1916.

In the year 1911, after exposing a large *Diceratherium* area of closely packed skeletal remains and securing parts of a *Dinohyus* skeleton, the border of a great *Moropus* area was exposed. In the year 1912 three skeletons of *Moropus* were secured, mingled with very abundant *Diceratherium* and portions of one skull and skeleton of *Dinohyus*. During 1913 and 1914 several more skeletons were found, and the outlines of a great *Moropus* bed were determined. In 1915 work was suspended. In 1916 the *Moropus* collections of the American Museum were completed (October 29), amounting in all to seventeen skeletons. In the five summers of excavation (1911-1914, 1916) an irregular area within a square of about thirty-six feet yielded nearly complete skulls of ten individuals and skeletal parts of seventeen more animals.

It was at first supposed that this accumulation of bones came from the drifting of a very large number of decomposing skeletons, but the early years of careful work soon revealed the very important fact that the greater part of this skeletal material belongs to a number of individuals. These individuals

¹ E. H. Barbour: The skull of *Moropus*. Nebr. Geol. Survey, vol. 3, pt. 2, 1908, pp. 209-216, pls. 1-2, figs. 1-5.

² The type of *Moropus elatus* Marsh has recently been determined by Mr. Harold Cook as of Upper Harrison age.

³ W. J. Holland and O. A. Peterson: The osteology of the Chalicotherioidea, with special reference to a mounted skeleton of *Moropus elatus* Marsh now installed in the Carnegie Museum. Mem. Carnegie Mus., vol. III, no. 2, Jan. 17, 1914, pp. 189-406, pls. xlviii-lxxvii, figs. 1-113.

have been assembled with a considerable degree of certainty as to the association: first, through the extremely careful records which were kept of the location of every bone in the quarry; second, through their propinquity; third, the careful fitting and articulation of the bones; finally, through careful comparative measurement of size. It now appears certain that few of the bones had drifted a long distance; they were mostly deposited not far from the carcasses to which they had belonged.

The last twelve months of laboratory work in the American Museum of Natural History has resulted in bringing together several skeletons which are practically complete, and certainly in more than one case belonging to one individual, together with a number of skeletons in which the association of the bones is probably but not certainly correct.

From this wonderful material it has been possible to supplement the full descriptions of this animal which were published in 1909 by Messrs. Holland and Peterson, and to give for the first time the absolute form and proportions, the pose, and the articulations of the fully adult *Moropus*, of very large size. This and other materials will soon be described by the present author.

In the meantime *Moropus* may be characterized as a forest-loving, slow-moving animal, not improbably frequenting rather swampy ground. The small head, relatively long neck, high fore quarters, short, downwardly sloping back, straight and elongated limbs, suggest a profile contour only paralleled by the forest-loving okapi among existing mammals. The foot structure, of course, is radically different from that of the okapi, but we should not regard it as *fossorial*, or of the digging type, because it is not correlated with a fossorial type of fore limb. It would appear that these great fore claws, in which the phalanges were sharply flexed, were used in pulling down the branches of trees and also as powerful weapons of defense.

A LONG-JAWED MASTODON SKELETON FROM SOUTH DAKOTA AND
PHYLOGENY OF THE PROBOSCIDEA

BY HENRY FAIRFIELD OSBORN

(Abstract)

Cope's family classifications were morphological and horizontal rather than phylogenetic and geological. Finding one or more single characters possessed in common at certain horizontal periods of geologic time by mammals in different lines of evolutionary descent, he seized on these common characters as convenient keys to classification. First¹ for the order Perissodactyla and then for the families of rhinoceroses² and titanotheres³ I have reached the opinion that Cope's method of morphological classification is untenable, that the only true and permanent classification is phylogenetic. Other paleontologists, however, have reached a different opinion.

¹ Fossil mammals of the Wasatch and Wind River beds. Collection of 1891. (With J. L. Wortman.) Bull. Am. Mus. Nat. Hist., vol. iv, art. xi, Oct. 20, 1892, pp. 81-147.

² Phylogeny of the rhinoceroses of Europe. Rhinoceros contributions No. 5. Bull. Am. Mus. Nat. Hist., vol. xiii, art. xix, Dec. 11, 1900, pp. 229-267.

³ The four phyla of Oligocene titanotheres. Bull. Am. Mus. Nat. Hist., vol. xvi, art. viii, Feb. 18, 1902, pp. 91-109.

The chief advantage of the vertical phylogenetic classification is that it brings animals together in similar or closely allied lines of evolutionary ascent; it corresponds with the branches and subbranches of the family tree. The chief difficulty with phylogenetic classification is a technical one, namely, to harmonize it with the Linnæan and the prevailing zoological system of family, subfamily, and generic nomenclature, which are alike based on affinities displayed between the existing terminal twigs of the branches and subbranches rather than on the phyletic ancestral lines which connect the twigs with their several ancestral branches. Sometimes the subfamilies proposed by zoologists conform to the phyletic lines discovered by paleontologists; sometimes they do not.

The present classification and nomenclature of the Proboscidea illustrates afresh the confusion, at first glimpse apparently hopeless, resulting from morphological classification and nomenclature of Linnæus and of various paleontologists, following the zoological standards, such as were embraced by Osborn. Upward of forty generic names have been applied to the mastodons and elephants, and, as pointed out by Matthew,⁴ there is no uniformity in the use of these generic terms, nor has any principle of arrangement been worked out by which we may at least *begin* an advance toward a permanent system of nomenclature of this highly important and interesting group.

In the present paper, which is the result of studies begun in 1902 and observations carried on in American and European museums, with the valuable aid of the recent rearrangement of the collections of Proboscidea in the American Museum of Natural History by Dr. W. D. Matthew, I essay a phylogenetic classification. This attempt, aided by the recent observations of Lull,⁵ Matthew,⁴ and Barbour,⁷ is preliminary to a more thorough review which is in preparation by the author.⁶

It will probably subserve clearness to present at once the following key to the proposed phylogenetic classification, in which are shown at least *eleven* distinct phyla of proboscidiæ, grouped into *five* subfamilies and *three* families.

ORDER PROBOSCIDEA

Families

DINOTHERES:

I. *Dinotheriida*, crested teeth, down-turned tusks.

II. *Mastodontida*, crested and cone teeth.

MASTODONTES. A. BUNOLOPHODONT, cone-and-crest-teeth mastodonts.

1. *Bunomastodontina*:

⁵ R. S. Lull: The evolution of the elephant. Am. Jour. Sci., vol. xxv, Mar., 1908, pp. 169-212, figs. 1-27, 4 charts; reprinted in Smiths. Report for 1908, No. 1909, pp. 641-67.

⁶ W. D. Matthew: The generic nomenclature of the Proboscidea. Read before the Paleontological Society, Pittsburgh, Jan. 1, 1918.

⁷ E. H. Barbour: Mammalian fossils from Devils Gulch. Nebraska Geol. Survey, vol. 4, pt. 1, Dec., 1913, pp. 177-190, pls. 1-13. A new longirostral mastodon from Cherry County, Nebraska. Nebraska Geol. Survey, vol. 4, pt. 14, Sept. 15, 1914, pp. 213-222, pls. 1-6, figs. 1-6 (tailpiece). A new longirostral mastodon from Nebraska. Tetrabelodon osborni, sp. nov. Am. Jour. Sci., vol. xii, June, 1916, pp. 522-529, figs. 1-4.

⁸ A memoir on the phylogeny of the Proboscidea, with illustrations of the principal American types of mastodon and elephants in the American Museum of Natural History.

- 1a. Longirostral, long-jawed, bunomastodonts, Africa, Eurasia, America.
- 1b. Rhynchotherine, beak-jawed, bunomastodonts, North America.
- 1c. Brevirostral, short-jawed, bunomastodonts, Asia, America.

B. ZYGLOPHODONT:

- 2. *Mastodontina*, typical mastodonts of Europe, Asia, America.

III. *Elephantida*:

STEGODONTS. C. BRACHYLOPHODONT, short-crowned, crested teeth.

- 3. *Stegodontina*, stegodonts of southern Asia.

ELEPHANTS. D. HYPSELOPHODONT, long-crowned, crested teeth.

- 4. *Loxodontina*:

- 4a. *Loxodonta antiquus*, straight-tusked elephants, Eurasia, Africa.
- 4b. *Loxodonta africanus*, African elephants.

- 5. *Elephantina*:

- 5a. *Euelephas primigenius*, mammoths, Eurasia, North America
- 5b. *Euelephas columbi*; *E. imperator*, American mammoths.
- 5c. *Elephas indicus*, Indian elephants.

The three traditional families, namely, the *Dinotheriida*, *Mastodontida*, and *Elephantida*, call for no comment.

The mastodonts may be divided into two subfamilies, namely, (1) the *Bunomastodontina*, which are clearly distinguished by the presence of cones growing in between the transverse crests and forming "trefoils," to use the term introduced by Cuvier in his description of the grinding teeth of *M. angustidens*. This was the first bunomastodont discovered and is the type of a great race of longirostral, long-jawed, short-limbed forms, which ranged widely from northern Africa over Europe, Asia, and North America. As shown also in the accompanying scheme, the bunomastodonts, which sprang from *Palaeomastodon* of the Oligocene of northern Africa and possibly as well from *Hemimastodon* of southern Asia, divide into three great, long-lived phyla, which may be distinguished as follows:

Longirostral, long-jawed, typified by the species *M. angustidens*.

Medirostral, beak-jawed, typified by *Rhynchotherium*.

Brevirostral, short-jawed, typified by the species *M. mirificus*.

The long-jawed and short-jawed phyla of bunomastodonts are comparatively well known in Europe, Asia, North and South America. The beak-jawed phylum, typified by the genus and species *Rhynchotherium tlascala** is provisionally arranged, because there is some uncertainty as to the position of the species *R. euhypodon* Cope, *R. (?) shepardi* Leidy, and *R. brevidens* Cope. The rhynchotherines are readily distinguished by jaws of medium length, which tend to turn downward into a long, depressed beak, somewhat like that of

* The specific name *tlascala* is suggested to the author by Dr. W. D. Matthew in reference to the locality in Mexico, Tlascala.

Dinotherium, in which the lower canines are laterally compressed, whereas in all the longirostral bunomastodonts the lower canines are vertically compressed.

All these *bunomastodontinae* are very readily distinguished from the typical *Mastodontinae*, a line which is relatively conservative in its evolution, since the "intermediate" molars remain trilophodont and the crests only feebly develop the intermediate cones, or trefolls. Singularly enough, the supposed north Asiatic ancestors of this phylum are not known. It first appears in the *M. borsoni* of the Pliocene of Europe.

The *Stegodontinae* may be distinguished as a phylum confined to Asia, in which the grinding teeth remain brachyodont, short-crowned, although a very large number of cross crests evolve, especially on the posterior grinding teeth. From an early member of this subfamily, perhaps of Middle Miocene time, were given off one or more branches of the elephant and mammoth phyla.

Rhynchotherium from Mexico.—Extract of letter from Doctor Falconer to M. Lartet, September 12, 1856:¹⁰ "At Genoa I saw a cast of a large lower jaw of a mastodon from Mexico, with an enormous *bec* abruptly deflected downwards and containing one very large lower incisor. The beak is much thicker than in *M. (Trilophodon) angustidens* and larger than in *M. (Tetralophodon) longirostris*. You know that every one (Laurillard, Gervais, etc.), have insisted on the absence of the lower incisors from both of the South American species. The outline of the jaw resembles very much the figure in Alcide D'Orbigny's Voyage, described by Laurillard as *M. andium*. The specimen is unpublished material and I was therefore only allowed to examine it very cursorily. The Genoese paleontologists had provisionally named it *Rhynchotherium*, from the enormous development of the beak, approaching *Dinotherium*."

The arrangement of the elephant and mammoth phyla is not clear at present, although it appears that four distinct subphyla developed. The first, to which the generic name *Loxodonta* applies, includes the Pleistocene and recent elephants of the African type, which by Falconer and other students of Asiatic forms are supposed to be related to the *L. namadicus* of the Lower Pliocene of the Siwaliks. The next phylum, *Euelephas*, by consent of all leading European authorities, begins with *E. planifrons* of Asia and Europe, Middle Pliocene. It includes *E. hysudricus* of the Upper Pliocene, passes into the *E. meridionalis* and *E. trogontherii* of the Lower Pliocene, and thence into *E. primigenius*, the woolly mammoth.

From a Middle Pliocene form, in a stage of evolution similar to that of *E. planifrons*, it is possible that the peculiarly American mammoths *E. columbi* and *E. imperator* may have been given off as a side phylum, but this is not yet determined. This leaves the typical elephant, *E. indicus*, as a related phylum, the ancestry of which has not yet been determined.

Thus the Proboscidea divide into at least six great phyla, to which the subfamily designations *Elephantinae*, *Euelephantinae*, *Loxodontinae*, *Stegodontinae*, *Mastodontinae*, *Bunomastodontinae*, may be given. There are also some reasons for separating the bunomastodonts into three phyla, which might be known as the *Longirostrinae*, *Rhynchorostrinae*, and *Brevirostrinae*, but this may be a somewhat premature opinion.

¹⁰ Charles Murchison: Paleontological Memoirs and Notes of the Late Hugh Falconer. A. M., M. D. 2 vols., 8vo. London, 1868, vol. II, pp. 74-75.

This discrete and profuse subfamily arrangement would be shocking to a "lumper" like our late colleague and honored friend, Dr. Richard Lydekker, who combined¹¹ all the mastodons and elephants into two genera, namely, *Mastodon* and *Elephas*. The application of *subfamily* names to these monophyletic, or similar polyphyletic ascending series, is considered preferable to the coining of a new taxonomic term.

The propriety of thus applying subfamily terms is disputed by some paleontologists, notably by my colleagues, W. D. Matthew and W. K. Gregory. The subfamily termination, *inae*, may, in the author's opinion, be adopted without any real exaggeration to express the fact that *many of these phyla have been distinct and separate from each other for enormous periods of geologic time*. This is real hereditary relationship in the family or subfamily sense. For example, it may be shown that the longirostral bunomastodont phylum began with *Palaomastodon* of the Upper Oligocene, and that this animal was already too specialized as a longirostral bunomastodont to constitute the ancestor of any other phylum than its own. This main longirostral phylum is geologically the oldest and phylogenetically the most complete. It illustrates one general law of mammalian evolution, namely, that a phylum having specialized in a certain character usually tends to evolve this character to an extreme; the long jaw of *Palaomastodon* goes on lengthening until in Lower Pliocene time it attains the great length observed in the forms recently described by Barbour¹² as *Eubelodon morrilli*, *Megabelodon lulli*.

In this longirostral phylum, as well as in the brevirostral bunomastodonts, the question of the application of the *generic* nomenclature of Linnæus is certainly a most puzzling one. Thirteen distinct generic names have been proposed for the longirostral bunomastodonts and six distinct generic names for the brevirostral bunomastodonts.

Several puzzling questions arise: first, how many generic names can consistently be applied within each of these phyla; second, which generic names in the long list shall be given precedence; third, shall the law of the technical priority of a name prevail, or shall we recognize only the priority of the first clear definition and conception of a genus which is based on one or more definite and clearly described characters of its genotypic species?

This whole question has been raised in the previous communication to the Paleontological Society by Doctor Matthew.¹³ I am disposed to recommend that certain well defined generic names may, after due consideration, be adopted by the Paleontological Society as *nomina servantur*. The selection of these names will be greatly facilitated by a true phylogenetic classification of the Proboscidea, to which the present outline is preliminary.

At 12.30 the Society adjourned for luncheon.

CONTINUATION OF SYMPOSIUM

At 2 p. m. the symposium was resumed, with the reading of a paper on the Mesozoic history by Doctor Stanton entitled

¹¹ Richard Lydekker: Catalogue of the Fossil Mammalia in the British Museum (Natural History). Pt. IV, The Order Ungulata, Suborder Proboscidea. 8vo. London, 1886, pp. xxiv, 233 (1).

¹² E. H. Barbour: Op. cit.

¹³ W. D. Matthew: Op. cit.

MESOZOIC HISTORY OF CENTRAL AMERICA AND THE WEST INDIES

BY T. W. STANTON

Discussion of this paper was deferred until the last one of the series of invertebrate paleontology was presented by the author, Doctor Vaughan.

CENOZOIC HISTORY OF CENTRAL AMERICA AND THE WEST INDIES

BY T. W. VAUGHAN

A general review of the problems connected with the history offered by invertebrate paleontology was brought out in the discussion of these papers, which occurred at this point. Prominent among the speakers were Messrs. Holland, Osborn, Vaughan, Merriam, Matthew, and Grabau.

The evidence on this history offered by vertebrate paleontology was given in the two following papers, discussion again being deferred:

RELATIONSHIPS OF THE MESOZOIC REPTILES OF NORTH AND SOUTH AMERICA

BY S. W. WILLISTON

AFFINITIES AND ORIGIN OF THE ANTILLEAN MAMMALS

BY W. D. MATTHEW

This portion of the symposium called forth still more discussion, in which Messrs. Merriam, Matthew, Osborn, Eigenmann, Grabau, Williston, and Price participated. During this discussion, Doctor Eigenmann was requested to give the evidence afforded by the fishes. His remarks entitled as below were highly interesting and appreciated.

FRESH-WATER FISH FAUNAS OF NORTH AND SOUTH AMERICA

BY C. H. EIGENMANN

In this discussion Doctor Grabau mentioned the work and results of Graham J. Mitchell on recent changes of level in Porto Rico.

*EVIDENCE OF RECENT CHANGES OF LEVEL IN PORTO RICO, AS SHOWN BY STUDIES IN THE PONCE DISTRICT¹*BY GRAHAM JOHN MITCHELL²

(Abstract)

With the inauguration of the Natural History Survey of Porto Rico, under the joint auspices of the New York Academy of Sciences and the Insular Gov-

¹ By permission of the Porto Rico Committee of the New York Academy of Sciences. Report on the geology of the Ponce district in preparation.

² Introduced by A. W. Grabau.

ernment of the Island, a study of the geology of the region was undertaken as one phase of the investigations. The first geological party to enter the field consisted of Doctors Charles P. Berkey and Clarence N. Fenner, who, during the summer of 1914, completed a reconnaissance of the island. Since that time an average of two parties a year have been sent into the field.

In his report¹ Doctor Berkey noted the occurrences of terraces 100 to 200 feet above the present sealevel, particularly on the south coast near Guayama, and attributed their origin to wave action. Subsequent investigators have substantiated this conclusion. Mr. A. K. Lobeck, however, after a study of the physiography of the island, concluded that there has been only a slight differential uplift of the western end of Porto Rico in very recent time, the maximum change being at Rincon, on the west coast, where an elevation of 40 feet occurs.

During the past summer a survey of the southwestern quarter of the island was made by the writer, that section being one which appeared favorable to the solution of the question of recent changes of level in Porto Rico. The evidence gathered in this study is summed up as follows:

1. One-half mile southwest of Juana Diaz, on the north bank of the Jacaguas River, the folder Tertiary beds are beveled and a deposit of silt, sand, and gravel 2 to 12 feet thick covers the surface. In this surface covering, at an elevation of 130 feet, are found numerous *Strombus pugilis*.

2. At kilometer 72.5 on the Ponce-Penuelas road recent marine fossils are found in finely stratified material of estuarine character. In this deposit a layer of black mud averaging one foot in thickness occurs at a depth of from 2 to 5 feet below the surface. In this black mud are found *Strombus pugilis*, *Lucina jamaicensis*, *Lucina tigrina*, *Arca tuberculosa*, and *Byssarca zebra*. These fossils are also found in other parts of this deposit, the elevation of which is 180 feet.

3. Across the west branch of the Canas River, just east of the above locality, the same species of fossils which occur at locality "2" are found in the stratified sands and gravels at a depth of 3½ feet below the surface and an elevation of 160 feet.

4. Southeast of Yauco, 1¼ miles, in the Rio Yauco Valley, abundant fossils are found in the surface covering of the river valley at an elevation of 150 feet. The fossils include *Murex elongatus*, *Arca rhombea*, *Lucina tigrina*, *Arca tuberculosa*, *Turritella imbricata*, *Pecten nucleus*, *Venus cancellata*, *Ostrea virginica*, and *Perna* sp.

5. East of Yauco, one-eighth of a mile, the pre-Tertiary rocks are truncated, and in the gravel and sand which mantels the beveled strata are found *Arca tuberculosa* and *Lucina tigrina*, occurring at depths of 1 to 2 feet below the surface. The elevation at this point is 200 feet.

6. On the coast southeast of Yauco a terraced surface bevels the Tertiary limestone at an elevation of 60 to 160 feet, the inner margin being marked in places by cliffing. The following fossils are found on this surface: *Strombus accitrinna*, *Fissurella nodosa*, *Arca rhombea*, and *Turbo pica*.

7. Just north of the lighthouse at Guanica the Tertiary limestone is beveled by terraces at levels of 10, 50, and 150 feet, and in the surface soil on the two

¹ Geological reconnaissance of Porto Rico. *Annals N. Y. Academy of Sciences*, vol. 26, 1916.

upper terraces are found *Arca tuberculosa*, *Lucina tigrina*, and *Turbo pica*. On the 10-foot level large numbers of these fossils are found in the lime, sand, and silt which coats this terrace.

8. East of Guanica, one-eighth of a mile, on the east side of the Susua Valley, a terrace at an elevation of 50 feet contains in the surface material the forms *Lucina jamaicensis*, *Arca tuberculosa*, and *Turbo pica*.

9. At the town of Ensenada (Central Guanica), the pre-Tertiary is truncated and a deposit of shells, muds, silt, and sand covers the surface to a maximum depth of 5 feet. The fossils occur at an elevation of 45 feet and include the following: *Murex elongatus*, *Isophyllia* sp., *Venus cancellata*, *Operculum* of *Turbo*, *Arca rhombea*, *Cerithium litteratum*, *Ostrea virginica*, and *Byssosarca zebra*.

10. On the south side of Pardas Bay, south of Ensenada, the Tertiary limestone is again terraced, its elevation being 65 to 100 feet, and the fossils *Arca rhombea*, *Arca tuberculosa*, and *Lucina jamaicensis* are found buried in the surface soil.

11. On Cape Rojo, in the southwest corner of Porto Rico, the San Juan formation, which has been interpreted by Doctor Berkey as a limesand of dune origin, is found at an elevation of 75 feet overlain by 3 feet of conglomerate consisting of well rounded pebbles. In the San Juan formation occurs a *Conus* very close to the recent form *Conus porto-ricanus*.

12. On Aguilla Point, the extreme southwestern portion of the island, recent gastropod shells are found in consolidated gravels at an elevation of 11 feet. At an elevation of 25 feet they occur on the beveled surfaces of the rocks which make up this point.

13. Three and three-quarters miles southwest of Mayaguez, on the coast near the reform school, a terrace is cut on the pre-Tertiary rocks at an elevation of 50 feet. The inner margin is marked by cliffing, and the following fossils are found in the surface soil: *Arca tuberculosa*, *Venus cancellata*, and *Lucina jamaicensis*.

The argument has been advanced by Mr. Lobeck that where recent fossils have been found in Porto Rico they are associated with Indian mounds. Such an interpretation, however, could not explain the existence of recent shells buried in stratified material of estuarian character at depths of from 2 to 5 feet. Furthermore, although in each of the 13 localities cited above the writer made careful search for artifacts, in no instance was evidence found to substantiate the Indian mound theory.

Based on the evidence presented in the 13 above-mentioned cases, the writer draws the following conclusions: With the recent changes of level of land and sea the old river valleys were embayed, allowing the sea to enter with its marine fauna and to lay down deposits of sand, silt, and mud. That these deposits (for example, localities No. 1, 2, 3, 4, 5, 8, and 9) were laid down in Quaternary time is evidenced by the fact that over 95 per cent of the fossils are of the same species as those living at the present time in the adjacent sea.

In the remaining instances (6, 7, 10, 11, 12, 13) the truncation of the underlying beds of limestone and other formations along the south and west coasts and the presence of cliffing at the inner margins of some of these terraces, together with the recent fossils found on the surface, are facts hard to explain if they are not in some way connected with the work of the sea.

In considering the question, Which has been the shifting element, the land or the sea? the evidence indicates a change in the elevation of the land. If the sealevel had varied, one should find some uniformity in terrace levels at particular stages. Such uniformity does not exist. In summing up the conclusions the writer feels justified in stating that there has been differential uplift of the land in Porto Rico in recent time, with a maximum change of 200 feet.

PRESENTATION OF PAPERS

After the completion of the symposium, the hour for adjournment not having arrived, the reading of papers was resumed with the presentation of an interesting account of the great confusion prevailing in the nomenclature of the Proboscidea. As a result of this paper, it was voted by the Society that the President should appoint a committee to consider the generic nomenclature of the Proboscidea and other groups of mammals and to report its recommendation at the next meeting. Doctor Matthew was appointed chairman of this committee.

GENERIC NOMENCLATURE OF THE PROBOSCIDEA

BY W. D. MATTHEW

(Abstract)

The nomenclature of the extinct Proboscidea is in a state of fearful confusion. Partial attempts to apply the rules of strict priority have made matters worse, and a consistent application of the rules will apparently result in setting aside every one of the names in current use, but the proper substitute names would require a whole series of arbitrary or questionable decisions. As it is wholly improbable that such substitute names would be uniformly, or even generally, accepted, and as the object of nomenclatorial procedure is to secure uniformity, the writer proposes that certain of the current names be submitted as *nomina conservanda* to the committee of the International Zoological Congress with the indorsement of the Paleontological Society.

At 6 p. m. the Society adjourned.

Tuesday evening the members and invited guests attended the annual dinner of the Society at the University Club.

SESSION OF WEDNESDAY, JANUARY 2

Wednesday morning, at 10 o'clock, the Society met in general session, with Vice-President Matthew in the chair.

REPORT OF THE AUDITING COMMITTEE

The only matter of business on hand was the report of the committee to audit the accounts of the Treasurer. The committee attested to the

correctness of these accounts, and it was thereupon voted by the Society that the report be accepted.

PRESENTATION OF PAPERS

The first paper of the morning was an interesting account of the Cretaceous strata of northwest Europe as interpreted from the fossil sponges. This was presented by the author and illustrated with a number of diagrams. It brought forth considerable discussion, in which Messrs. Reeds, Grabau, Merriam, Dickerson, and Holland took part, with replies by Miss O'Connell.

CRETACEOUS OVERLAPS IN NORTHWEST EUROPE AND THEIR BEARING ON THE BATHYMETRIC DISTRIBUTION OF THE CRETACEOUS SILICISPONGIÆ

BY MARJORIE O'CONNELL

(Abstract)

While studying and arranging a collection of over a thousand specimens of Cretaceous Silicispongæ in the American Museum of Natural History, the author was led to consider the lithic character and areal distribution of the sediments in which these fossils were found and the problem of the bathymetric range of European Cretaceous Silicispongæ. The bathymetric ranges of Cretaceous species which have persisted to the present time will be given and there will be a brief discussion of the conclusions which it is permissible to draw from such data. The significance of the overlaps of the sponge-bearing and other Cretaceous strata of Europe will be considered and the value of the lithogenetic method of study in the determination of habits of ancient organisms will be dwelt on.

The next paper, which was amply illustrated by very clear and interesting lantern slides, was of especial interest on account of dealing with the region considered in the symposium. It was presented by the author, who replied to discussions by Messrs. Burling and Matthew.

NEW BATHYMETRICAL MAP OF THE WEST INDIES REGION

BY CHESTER A. REEDS

(Abstract)

During 1916 all of the Hydrographic and Coast and Geodetic Survey charts bearing on the West Indian region were assembled and, with chart 1290 as a base, all soundings were plotted. The one-hundredth fathom line was then drawn, also the five hundredth, and with a contour interval of 500 fathoms successive depths were sketched down to 4,500 fathoms. The result is a contour map somewhat different from its predecessors. When modeled on a globe surface the features of the submarine topography are even more striking.

Doctor Grabau then presented a study of one of the factors in faunal development, which brought forth considerable discussion from Messrs. Reeds, Parks, Williston, Matthew, Ortman, Merriam, and Bassler. This paper was illustrated by paleogeographic maps showing the development of North America in Silurian and Devonian times.

ISOLATION AS A FACTOR IN THE DEVELOPMENT OF PALEOZOIC FAUNAS

BY AMADEUS W. GRABAU

(Abstract)

Whenever a portion of a cosmopolitan fauna is segregated in an embayment of the Red Sea type, the segregated fauna being in large measure prevented from intercrossing with the main stock, and so remaining true to type, develops orthogenetically into a modified fauna which, when once established, remains true to the new type and frequently thereafter becomes a dominant one. The faunas which it is believed have thus come into existence are, among others, the Brassfield fauna of the Siluric, the Helderbergian fauna of the Lower Devonic, the eastern Michigan and Ontario Upper Hamilton fauna, and the Ithaca fauna. Illustrations of these will be given.

At 12.30 the Society adjourned for luncheon.

At 2 p. m. the members were called to order by Vice-President Grabau, who announced that by curtailing the longer papers somewhat separate sessions would not be necessary to complete the program.

The first paper of the afternoon session was presented by the Secretary for the author and dealt with new discoveries in the early Paleozoic rocks of Alaska.

AN ORDOVICIAN FAUNA FROM SOUTHEASTERN ALASKA

BY EDWIN KIRK

(Abstract)

The oldest fossiliferous sediments hitherto known in southeastern Alaska were of Silurian age. The discovery last season of early Ordovician sediments is therefore of considerable interest.

Extending along the shore for a considerable distance to either side of the town of Wrangell is a great series of highly metamorphosed sediments. These consist almost entirely of greenstones, crystalline schists, and argillites. A block of fossiliferous slate was found near Wrangell by Prindle some years ago. These fossils were reported by Girty as being anything from Devonian to Recent in age. If Paleozoic, he suggested that the age was probably Devonian or Carboniferous. The fossils were in a very poor state of preservation, and the prevailing opinion has been that the block of slate was an erratic. The beds at Wrangell have generally been assigned to the mainland belt of supposed Carboniferous-Mesozoic, that ranges from the Ketchikan area at the south to the Juneau and Chilkat areas at the north.

On the point forming the south side of Wrangell harbor, graptolites were found that seem to fix the age of this Wrangell series. The graptolites are found both in slate and schist. The slate specimens are unrecognizable unless one knows they are graptolites to begin with. The specimens occurring in the schist, though badly preserved, are easily recognizable as graptolites, and the generic affinities of one individual may be determined with a fair degree of certainty.

The specimen of chief importance and interest is referred with little doubt to *Tetragraptus*. It is very like a large species known in the early Ordovician of Idaho. Other specimens not so well preserved strongly suggest *Phyllograptus*. These fossils clearly point to the Beekmantown age of the sediments.

On Long Island and on Dall Island, on the southwest coast of Prince of Wales Island, are schistose sediments similar to those at Wrangell. They are even more metamorphosed than the Wrangell series where I saw them, and it seems doubtful if fossils would be preserved in them. They may well be of the same age, however. These beds fall in Brooks Wales series. As defined, the Wales series also probably included rocks of Silurian age.

Aside from establishing the presence of Ordovician sediments in southeastern Alaska, this find is of interest as throwing in doubt the generally accepted views as to the age of the mainland belt of sediments west of the Coast Range batholith. It has generally been assumed that this belt was of Carboniferous and Mesozoic age, with the Mesozoic as the more important element. It will probably be found that, in addition to the Carboniferous and Mesozoic, which are undoubtedly present at some points, all the Paleozoic elements elsewhere known in southeastern Alaska are represented in this coastal belt.

A brief summary of an extensive paper on the extinct Camelidæ was then presented by the author and was discussed by Messrs. Peterson and the author.

AFFINITIES AND PHYLOGENY OF THE EXTINCT CAMELIDÆ

BY W. D. MATTHEW

(Abstract)

The author has in preparation a revision of the extinct Camelidæ, preliminary results of which are presented. The relationship of the supposed Eocene ancestors of the Camelidæ is discussed, but they are not included in the family. The North American genera and species are revised and their relations are discussed. They afford exceptionally direct phyla from Oligocene to Pleistocene, with two distinct side branches, the giraffe-camels and gazelle-camels, and several minor twigs. The Old World camels belong to the genera *Ptilauchenia* and *Camelus*, the latter not found in America, and are of Pliocene to recent age. The South American camels form a compact group of two closely related genera, *Palaolama* and *Auchenia*, and are of Pleistocene and recent age. Their nearest North American relatives are the smaller species of *Camelops* (Pleistocene), and they are doubtless derived from *Ptilauchenia*, but not from any known species.

The two following papers on the stratigraphy and paleontology of the Canadian Cordillera were presented together by Mr. Burling, who illustrated them by diagrams and maps. Results of this stratigraphic work by Mr. Drysdale and Mr. Burling, the former of whom lost his life in this field-work, were discussed by Messrs. Parks, Grabau, and Burling.

ROCKY MOUNTAINS SECTION IN THE VICINITY OF WHITEMANS PASS

BY C. W. DRYSDALE AND L. D. BURLING

(Abstract)

This paper will describe the results of the fatal reconnaissance trip undertaken by the late Mr. Drysdale and the writer during the early part of the last field season.

The line of section begins west of Cochrane, Alberta, and proceeds in an almost straight southwesterly direction across Whitemans Pass to a point on the Kootenay River east of the Windermere mining district of British Columbia.

The region traversed by the section, which crosses the strike of the rocks, is broken into a series of longitudinal blocks, each shoved over its neighbor to the east and all more or less similarly tilted. The fossils secured show the thrust-faults between to be of large magnitude, but they coincide so largely with the valleys and with the strike and the local folding in their vicinity is so subordinate that the presence of faulting has not been recognized. Dawson is the only geologist who has made a previous crossing.

FURTHER LIGHT ON THE EARLIER STRATIGRAPHY OF THE CANADIAN CORDILLERA

BY LANCASTER D. BURLING

(Abstract)

This paper will deal with some of the more important of the discoveries of the 1917 field season.

New evidence was secured bearing on the question of the age relationships of the Lower Cambrian and Beltian rocks of British Columbia, Alberta, and Montana.

Careful search in the so-called "Castle Mountain" limestones at the head of Nyack Creek, Montana, yielded abundant casts of salt crystals, but no fossils. Their Siyeh age is almost unquestioned.

The Mount Robson region was visited and collections secured from many horizons, all the Cambrian and Ordovician formations above the lowest quartzitic sandstones being represented. Many doubtful points in the stratigraphy were cleared up—such, for example, as the true position of the *Extinguisher* ("Billings Butte") fauna, etcetera. Evidence secured would seem to indicate that while the *Callavia* and *Olenellus* zones are hardly to be separated as such in this region, *Callavia* does appear alone in the section first, later mingles with *Olenellus*, and finally disappears, leaving *Olenellus* alone.

The *Albertella* fauna was traced to the north, south, and east and further

collections secured from the horizon itself and from the rocks immediately above and below.

The Cambro-Devonian boundary was examined in numerous places, with the following results: On Roche Miette the Devonian has been described as separated from the Cambrian (in which the highest fossils now appear to be of Middle Cambrian age) by a series of beds tentatively referred to the Silurian. Further collections from these rocks appear to place them in the Devonian. In North Kootenay Pass the Middle Cambrian is separated from the Devonian by many hundreds of feet of apparently unfossiliferous strata. In the Beaverfoot Range near Golden the Devonian is absent, but the section includes several thousand feet of fossiliferous Upper Cambrian and Ordovician, up to and including the Richmond, east of Lake Minnewanka, and in the Sawback Range and upper Columbia Lake sections the Devonian rests on a series of beds whose fauna is comparable in many respects with that of the Ozarkian.

Many additional specimens of Triassic (?) fish were secured from the fish locality discovered in 1915 in the "Jurassic fault block" near Massive, west of Banff, Alberta.

Additional collections were made from the fossil locality discovered by Mr. Drysdale in the Laurie Metargillite near the Laurie mine, west of Glacier. These are limited to crinoid stems, but appear to indicate that the Laurie Metargillite is Upper Paleozoic in age.

Additional collections were secured by Mr. Bancroft and the writer from the general horizon in the Slovan series containing the doubtful fossils first discovered by Messrs. Drysdale and Bancroft in 1916. These have been examined by Mr. Kindle, who reports that they appear to be of Pennsylvanian age.

Professor Williston followed with a paper on the evolution of vertebræ, which was illustrated by numerous lantern slides and discussed by Doctor Merriam.

EVOLUTION OF VERTEBRÆ

BY S. W. WILLISTON

(Abstract)

The evolution of the holospondylous vertebra from the primitive embolomorous type is shown in the gradual decrease in size of the hypocentrum in the caudal vertebræ of the rhachitomous amphibians and the atlas of primitive reptiles to a wedge-shaped form not much larger than the dorsal intercentra of primitive reptiles and by the corresponding increase in size of the embolomorous disklike pleurocentrum into the body of the centrum of the primitive reptiles. It is evident that the rhachitomous amphibians have no immediate ancestral relationships with the reptiles, which must have sprung directly from the Embolomeri, probably in Mississippian times.

A second interesting paper on vertebrate paleontology, dealing with the paleopathology of vertebrates, was presented by Professor Williston for the author. This paper, which was likewise well illustrated with lantern slides, was discussed by Messrs. Williston, Merriam, and Grabau.

DISEASES OF THE MOSASAURS

BY ROY L. MOODIE

(Abstract)

During the Cretaceous, diseases of animals reached a maximum of development in the mosasaurs, dinosaurs, plesiosaurs, and their associates. The number of diseases known to have afflicted these animals are numerous and varied. Some of them are apparently identical with the diseases of animals and man today. Others have probably become extinct with the race of animals which they afflicted. The diseases of the mosasaurs may be taken as an example of the diseases of the Cretaceous. Their importance may be seen from the graph showing the general geological development of disease. The diseases which afflicted the mosasaurs, such as caries and pyorrhea, were common in geological time. Others, such as periostitis and necroses, are not so common, but are evident in the group. The paper will be illustrated by lantern slides showing examples of diseases of the mosasaurs.

(This paper is not to be published separately, but is a part of a monograph, under preparation, on "Paleopathology, a study of the antiquity of disease.")

A paper dealing with the paleobotanic side of paleontology was next presented by the author, who illustrated his remarks with a number of especially well preserved specimens.

REPORT ON A COLLECTION OF OLIGOCENE PLANT FOSSILS FROM MONTANA

BY O. E. JENNINGS

(Abstract)

A report on a collection of about two hundred leaf-impressions collected a few years ago by Mr. Earl Douglass, mostly from the White River beds near Missoula, Montana, and now in the Carnegie Museum.

The specimens are in a fine volcanic ash and are excellently preserved. There are fourteen species represented, five of these being conifers, the remainder being broad-leaved trees, with the exception of a fragment of a leaf of a sedge. The most abundant species is *Carpinus grandis* Unger, other common species being *Tarodium dubium* (Sternberg) Heer and a *Sequoia* closely related to *S. coultsi* Heer. Among notable species for North America are *Chamaecyparis chrensacardi* Heer and *Thuopsis gracilis* Heer.

There was then presented by the author and discussed by Doctor Matthew the following paper, illustrated by lantern slides:

NEW TILLODONT SKULL FROM THE HUERFANO BASIN, COLORADO

BY WALTER GRANGER

(Abstract)

Our knowledge of the skull and dentition of the large Middle Eocene Tillodonts has previously been derived almost wholly from a single specimen from

the Bridger Basin and preserved in the Marsh collection at Yale. While making a preliminary examination of the Huerfano Basin in 1916 the author secured a nearly perfect skull and jaws of one of these forms. This new specimen appears to be generically distinct from *Tillotherium* of Marsh and close to Ledy's *Trogosus*, a more primitive form from the Lower Bridger, in which the second pair of incisors in the lower jaw is still present. A study of the new Tillodont and associated material from the uppermost Huerfano leads to the belief that this horizon is slightly older than the Lower Bridger.

The following two papers on the invertebrate paleontology and stratigraphy of the West Coast were combined into a single paper by their author, who illustrated his discussion with diagrams. These papers were discussed by Messrs. Matthew, Grabau, Bassler, and Miss O'Connell.

MOLLUSCA OF THE CARRIZO CREEK BEDS AND THEIR CARIBBEAN AFFINITIES

BY ROY E. DICKERSON

(Abstract)

The fauna obtained from the Tertiary beds near Carrizo Creek, San Diego County, California, have yielded several unique echinoids and corals. The echinoids were described by Doctor Kew two years ago, but unfortunately he did not obtain any direct faunal connection with other Tertiary horizons. During the past year Dr. T. Wayland Vaughan described the corals obtained from these beds and he recognized the Caribbean affinities of these forms, and from this study concluded that the beds were Pliocene in age. The mollusca obtained by Kew, Buwalda, and English confirm Vaughan's conclusions concerning the Caribbean affinities of this interesting group of marine invertebrates. Several species appear to be identical with forms which are characteristic of the Gatun formations of Miocene age.

PROPOSED CORRELATION OF THE PACIFIC AND ATLANTIC EOCENE

BY ROY E. DICKERSON

(Abstract)

Identical species, similar stages of generic evolution, and the mutations of *Venericardia planicosta* all show a much stronger relationship of the Tejon group to the three lower formations of the Gulf province—the Midway, Wilcox, and Claiborne—than was suspected. Tejon time was long and was probably equivalent to Midway (in part, at least), Wilcox, and Claiborne eons. The Jackson may be represented by the upper portion of the rhyolitic tuffs, the clay rock of Turner.

This study confirms and modifies somewhat the former conclusion "that the Martinez is not only equivalent to a portion of the Midway, but represents a still earlier stage of the Eocene as well." The generic relations between the Tejon and Midway are so close that it seems probable that they are correlative, at least in part. Possibly the Martinez is the marine equivalent of the Puerco and Torrejon of New Mexico—that is, Paleocene.

	Pacific province		Gulf province
Tejon	<i>Siphonalia sutterensis</i> zone	}	Claiborne
	<i>Balanophyllia variabilis</i> zone		
	<i>Rimella simplex</i> zone		{ Lower Claiborne Wilcox
	<i>Turbinolia</i> zone		Midway
Martinez	<i>Solen stantoni</i> zone	}	Puerco and Torrejon (?)
	<i>Trochocyathus zitteli</i> zone		
	<i>Meretrix dalli</i> zone		

New occurrences of glacial deposits in the Paleozoic rocks of southeastern Alaska were described in the next paper, which was presented for the author by the Secretary and illustrated by specimens.

PALEOZOIC GLACIATION IN SOUTHEASTERN ALASKA

BY EDWIN KIRK

(Abstract)

Paleozoic glaciation has not hitherto been recognized in Alaska. During the past field season a tillite of Silurian age was found in southeastern Alaska. Fairly conclusive evidence of Permo-Carboniferous glaciation was also secured. Conglomerates in the Devonian suggested the possibility of glacial beds in that period, but owing to lack of time and unfavorable weather conditions it was not possible to secure either positive or negative evidence as to their origin. The best exposures of the Silurian glacial beds seen were on Heceta Island, although good outcrops are to be found on the south shore of Kosciusko Island, about 15 miles to the north. Apparently the same beds occur along El Capitan passage between Kosciusko and Prince of Wales Islands. At the north end of Kuiu Island, some 125 miles to the north, a boulder bed holds the same stratigraphic position and I believe represents the same glacial deposit. Kosciusko and Heceta Islands, where the best Silurian glacial deposits are to be found, lie between 55° and 60° north latitude and 133° and 134° west longitude. These islands are situated on the west coast of Prince of Wales Island, toward the northern end.

The most favorable locality for an examination of the conglomerate is in the large bay about midway on the north shore of Heceta Island. The coast here is well protected from storms and there is a continuous outcrop of the limestone underlying the conglomerate, the conglomerate itself, and the overlying limestone. In places the conglomerate is well broken down by weathering, making the collection of pebbles and boulders an easy matter. As exposed, the beds outcrop along the shore between tide and levels and give an outcrop perhaps 2,000 to 3,000 feet in length.

The glacial conglomerate is under- and overlain by fossiliferous marine limestones. The succession of beds is clearly shown and unmistakable. The same relations can even more clearly be seen on the bold cliff at the east end of Heceta Island as to the upper limit of the conglomerate. The relations of the conglomerate to the underlying limestone are well shown on Kosciusko Island. The strata as a whole in this region are badly disturbed and, as is

the case throughout southeastern Alaska, contacts are very poorly shown, being, as a rule, indicated by an indentation of the shoreline and a depression running back into the timber. At present, therefore, although the relative positions of stratigraphic units are obvious, the character of the unconformity and the nature of the passage beds are poorly known.

The limestone series overlying the conglomerate carries a rich *Conchidium* fauna. In certain thin beds the rock is almost wholly made up of the brachiopods. This fauna appears to be identical with that of the Meade Point limestone of the Wrights and Kindle. The type exposure of the latter is at the northern end of Kuiu Island. At the base of the limestone at this locality is a boulder bed which I believe to be glacial in origin and to be correlated with the conglomerate of Heceta. The limestones below the conglomerate likewise carry a rich fauna consisting of pentameroids, corals, and gasteropods. The general aspect of both faunas seems to place them as approximately late Niagaran in age.

The conglomerate itself has a thickness of between 1,000 and 1,500 feet. In the main the conglomerate appears to consist of heterogeneous, unstratified, or poorly stratified material. Rarely lenticular bands of cross-bedded sandstone occur in the mass. These are clearly water laid and indicate current action.

The boulders in the tillite range in size up to two or three feet in length, as seen. The boulders consist of greenstone, graywacke, limestone, and various types of igneous rocks. Limestone boulders are scarce. All the boulders are smoothed and rounded. Facetted boulders are numerous and, given the proper type of rock, characteristic glacial scratches are common. The scratches show best on the fine-grained, dense greenstone. Limestone boulders and certain types of igneous rocks do not show them at all. The shoreline is strewn with these pebbles and boulders, which were undoubtedly derived from the conglomerate, as they are not to be found on the adjacent limestone shores. All the material collected was taken from the conglomerate itself, however. This is well broken down by weathering in some places, and the pebbles may be picked out with the fingers or tapped out with the hammer. When fresh the conglomerate, as a rule, is massive and exceedingly hard. The lantern slides will give a good idea as to the character of the conglomerate and nature of the crops as shown on the north shore of Heceta Island. Some of the boulders seen are entirely free and others are still partially embedded in the conglomerate.

The nature of the deposit is such as to suggest a till. The heterogeneous character of the boulders, both as regards size and material and the apparent lack of stratification in the main, points to a true till rather than a submarine bed of ice-transported glaciated material. Such evidence as is at hand indicates that the Heceta area was very near the shoreline and might easily have been land while the glacial material was being deposited. The whole Silurian section, which at its maximum farther north has a thickness of several thousand feet, thins out to the south and may prove to be absent at the south end of Prince of Wales Island.

In Pybus Bay, Admiralty Island, and on the Screen Islands off the west shore of Etolin Island are conglomerates strongly suggesting glacial material. In both cases these overlie high Carboniferous beds which have been corre-

lated by Girty with the Gschellian. Overlying the conglomerates are Middle Triassic beds. Where seen, the conglomerates had not weathered down and it was not possible to obtain loose boulders which might show scratches. Faceted boulders occur in the conglomerate, however. It will probably be found that this is a true glacial deposit and to be correlated with the conglomerate described by Cairnes near the Alaskan-Canadian boundary. A conglomerate similar to that described above underlies the Middle Triassic rocks of Dall Head, Gravina Island, and may prove of the same age and of similar character.

In the *Stringocephalus* limestone zone of the Middle Devonian small faceted pebbles up to $2\frac{1}{2}$ inches in length are of fairly frequent occurrence at one locality on the west coast of Prince of Wales Island. In Freshwater Bay and in Port Frederick, which lie near the northern end of Chicagoff Island, some 250 miles to the north, conglomerates occur in the Middle Devonian. Rounded boulders up to 2 feet in diameter were seen. They are very unlike normal sedimentary conglomerates. Should the boulders in the Devonian prove glacial, a somewhat different origin would probably be postulated for the conglomerates themselves. These are thin, ranging in thickness up to 25 feet or so, and would be more easily explained perhaps as consisting of berg-borne material, though glacial in origin. Bottoms of a similar nature are even now to be found in the channels of southeastern Alaska.

Throughout the Paleozoic section in southeastern Alaska are vast thicknesses of volcanic material, tuffs, breccias, and flows. Considering the sediments as a whole, climatic conditions through the Paleozoic do not seem to have been very different from those of comparatively recent times and physical conditions may have been very nearly the same.

Some of the results of a monographic study of American Tertiary Cyclostome bryozoa were presented by the junior author in the following paper, which was illustrated by lantern slides and specimens and discussed by Doctor Grabau.

PRINCIPLES OF CLASSIFICATION OF CYCLOSTOME BRYOZOA

BY F. CANU AND R. S. BASSLER

(Abstract)

During the preparation of a monograph on American Tertiary bryozoa the authors extended their study of the Cyclostome bryozoa to the Cretaceous and recent forms in order to arrive at some definite data for the natural classification of this group. As the zoecial form is practically the same in all the Cyclostome bryozoa, it is impossible to base a classification on this as is done in the other groups of this class. Hitherto the classification of the Cyclostomata has been based almost entirely on the form of the colony or zoarium, although it has always been realized that this was a very unnatural basis. The present authors have found that the ovicell, the marsupium-like organ which is developed on Cyclostome bryozoa, affords a natural basis of classification and the families and genera group themselves according to the position and form of this organ.

There was then presented by the author a paper on the invertebrate paleontology of a new West Coast Tertiary formation, which was discussed by Doctor Dickerson, with replies by the author.

FAUNA OF THE MEGANOS GROUP

BY B. L. CLARK

An interesting fauna of fossil vertebrates was described in the following paper:

FOSSIL MAMMALS OF THE TIFFANY BEDS

BY W. D. MATTHEW AND WALTER GRANGER

(Abstract)

The Tiffany beds are a local phase at the base of the Wasatch north of the San Juan River, in southern Colorado. Fossil mammals were first found there by J. W. Gidley, on whose invitation Mr. Granger explored the deposit in 1916 for the American Museum. A small but interesting fauna was secured there, regarded as of uppermost Paleocene age, equivalent to the Clark Fork beds at the base of the Bighorn Wasatch. The fauna includes several new or little known genera of minute size, but of considerable paleontologic interest.

A paper by President Merriam on the Pliocene of Idaho was next on the program, but its presentation had to be omitted because the material illustrating it had not arrived.

FAUNA OF THE IDAHO TULARE PLIOCENE OF THE PACIFIC COAST REGION

BY J. C. MERRIAM

President Merriam then took the chair and called for a paper on vertebrate paleontology, of which the author presented an abstract. This was discussed by Doctor Matthew.

REVISION OF THE PSEUDOTAPIRS OF THE NORTH AMERICAN EOCENE

BY O. A. PETERSON

(Abstract)

This abstract is taken from the general report on the Vertebrata of the Upper Eocene of the Uinta Basin, Utah, ready for publication. In this review is included two new genera of pseudotapirs from the Upper Eocene. A new family and two new subfamilies are proposed.

A short paper on American fossil rhinoceroses was then presented by Doctor Matthew and discussed by Professor Merriam.

NOTES ON THE AMERICAN PLIOCENE RHINOCEROSSES

BY W. D. MATTHEW

(Abstract)

Three genera of rhinoceroses occur in our Pliocene—*Aphelops*, *Peraceras*, and *Teleoceras*. They are distinct in the proportions of the skull, character of the horn-cores, upper and lower tusks, reduction of premolar teeth, hypsodonty of molar teeth, and by the proportions of limbs and feet. Although some or all may be derived from Old World ancestry, these genera are limited to North America and are distinct specializations from any of the various rhinoceros phyla of the Old World. They became extinct apparently before the end of the Pliocene.

New Upper Eocene mammals from Utah were then very briefly described by Mr. Peterson, who had prepared a much longer paper on the subject.

NEW ARTIODACTYLS FROM THE UPPER EOCENE OF THE UINTA BASIN, UTAH

BY O. A. PETERSON

(Abstract)

The paper is an abstract taken from the general report on the Vertebrata of the Upper Eocene of the Uinta Basin, Utah, now ready for publication.

A number of new genera of the subfamily Homacodontinae are first taken up. Secondly, it gives a short description of an American *Anoplothere* and its relation to *Diplobune* of Europe. Thirdly, a brief description and complete restoration of a new oreodont from the Upper Eocene. And fourthly, a description of a new Eocene hypertragulid and a review of the relationship between the Uinta and the Oligocene genera of the Hypertragulidae.

A paper on stratigraphy and invertebrate paleontology was next in order and was presented by the senior author. Discussed by Messrs. Dickerson and Grabau.

MARINE OLIGOCENE OF THE WEST COAST OF NORTH AMERICA

BY B. L. CLARK AND RALPH ARNOLD

(Abstract)

A general survey of the known data concerning the paleogeography, climatic conditions, and faunal relationships of the Oligocene as found in California, Oregon, Washington, and Vancouver Island.

The marine Mesozoic and Tertiary sediments of the West Coast were, for the most part, laid down in broad geosynclinal troughs, the axes of which paralleled that of the present ranges. The Tertiary sediments accumulated in these slowly sinking troughs to an enormous thickness. Roughly estimated, there are at least 40,000 feet of sediments of Tertiary age in the Coast Ranges; of this fully 10,000 feet belong to that period of time which is here referred

to the Oligocene. In Washington there was apparently a trough of deposition during the Oligocene time which extended from the Puget Sound district south between the Olympics and the Cascades into western Oregon. In California there was one large trough of deposition which extended from the region of Mount Diablo, middle California, to at least as far south as the San Emigdio Mountains, at the south end of the San Joaquin Valley, a distance north and south of over 200 miles. The axis of this trough, as indicated by the distribution of the organic shales, was in the eastern Coast Ranges. In the western Coast Ranges the Oligocene where present is represented by the shallow-water deposits; it is absent over large areas in this western field.

There are two general faunas known from the marine Oligocene deposits of the west coast. They very probably belong to two distinct epochs of deposition. The name San Lorenzo group is applied to the beds in which the lower fauna is found; the beds from which the upper fauna comes are referred to the Seattle group. The fauna of the Seattle group has not been determined in California for a certainty. The type section of the San Lorenzo is in the Santa Cruz Mountains of California. The fauna of the San Lorenzo group shows a closer relationship to that of the Tejon (Upper Eocene) than does that of the Seattle. On the other hand, the fauna of the Seattle group shows closer affinities to that of the Lower Miocene than does the San Lorenzo. These two Oligocene faunas show a much closer relationship to each other than does the one to the Eocene and the other to the Miocene.

In the absence of the author, Professor Merriam then read the final paper of the program.

THE QUESTION OF PALAEOECOLOGY

BY F. E. CLEMENTS¹

The following four papers of the program were read by title:

NOTE ON THE EVOLUTION OF THE FEMORAL TROCHANTERS IN REPTILES AND MAMMALS

BY WILLIAM H. GREGORY

CARBONIFEROUS SPECIES OF "ZAPHRENTIS"

BY G. H. CHADWICK

EXTINCT VERTEBRATE FAUNAS FROM THE BADLANDS OF BAUTISTA CREEK AND SAN TIMOTEO CANYON OF SOUTHERN CALIFORNIA

BY CHILDS FRICK

NOTES ON EIFEL BRACHIOPODS

BY G. H. CHADWICK

On motion, at 6 p. m. the Society adjourned.

¹ Introduced by J. C. Merriam.

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E. KOKEN, died November 24, 1912.

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SAMUEL CALVIN, died April 17, 1911.

WILLIAM B. CLARK, died July 27, 1917.

ORVILLE A. DERBY, died November 27, 1915.

WILLIAM M. FONTAINE, died April 30, 1913.

THEODORE M. GILL, died September 25, 1914.

ROBERT H. GORDON, died May 10, 1910.

J. C. HAWVER, died May 15, 1914.

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HENRY M. SEELY, died May 4, 1917.

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MINUTES OF THE EIGHTH ANNUAL MEETING OF THE PACIFIC COAST
SECTION OF THE PALEONTOLOGICAL SOCIETY

BY CHESTER STOCK, *Secretary*

The eighth annual meeting of the Pacific Coast Section of the Paleontological Society was held at Stanford University on April 6 and 7, 1917, the Society participating in the second annual meeting of the Pacific Division of the American Association for the Advancement of Science. A short, joint session with the Geological Society and the Seismological Society was held on April 6, at which time Prof. John C. Merriam spoke on preparedness. At the conclusion of Professor Merriam's address, the meeting adjourned, and the Paleontological Society was called to order in separate session by Dr. J. P. Buwalda at 3.15 o'clock, in room 360, Mineralogy Building.

ELECTION OF OFFICERS

The following officers were elected for the ensuing year:

President, BRUCE L. CLARK, University of California.

Vice-President, CHESTER STOCK, University of California.

Secretary-Treasurer, CHESTER STOCK, University of California.

PRESENTATION OF PAPERS

The following papers were then read:

*SYSTEMATIC POSITION OF THE DIRE WOLVES OF THE AMERICAN
PLEISTOCENE*

BY J. C. MERRIAM

*NOTE ON THE OCCURRENCE OF A MAMMALIAN JAW, PRESUMABLY FROM
THE TRUCKEE BEDS OF WESTERN NEVADA*

BY J. C. JONES

(Abstract)

During the summer of 1916 a small mammalian jaw came into the possession of the University of Nevada that had been found in digging a shallow well near Washoe City, Nevada. While the jaw was found in the recent alluvium at present covering the greater part of the floor of Washoe Valley, yet the only sedimentary beds from which it could have been eroded are similar in composition to the Truckee beds and believed to be of the same age.

Read by title.

PINNIPEDS FROM MIOCENE AND PLEISTOCENE DEPOSITS OF CALIFORNIA

BY REMINGTON KELLOGG

(Abstract)

A new genus and species of sea-lion from the Temblor, together with seal remains from the Santa Margarita and San Pedro, are described. The discussion includes a résumé of current theories regarding origin of the Pinnipedia.

PUMA-LIKE CATS OF RANCHO LA BREA

BY J. C. MERRIAM

*GRAVIGRADE EDENTATES IN LATER TERTIARY DEPOSITS OF NORTH
AMERICA*

BY CHESTER STOCK

(Abstract)

A review of occurrence of gravigrade edentates in Miocene and Pliocene deposits of North America. Particular attention is directed to recent discoveries

of ground-sloth remains in the Rattlesnake Lower Pliocene of eastern Oregon and in Lower Pliocene beds exposed along San Pablo Bay, California.

RELATIONSHIPS OF RECENT AND FOSSIL INVERTEBRATE FAUNAS ON THE WEST SIDE OF THE ISTHMUS OF PANAMA TO THOSE ON THE EAST SIDE

BY IDA S. OLDBOYD

(Abstract)

The range of various invertebrate species of the marine provinces to the west and east of the Isthmus of Panama is discussed, and attention directed to forms common to both sides of the isthmus. The report includes a statement concerning origin of certain of these species from a common stock, as well as observations on former trans-Panamic marine connections.

TROPITIDÆ OF THE UPPER TRIASSIC OF CALIFORNIA

BY J. P. SMITH

(Abstract)

A series of species of *Tropites* and near relatives are exhibited, showing evolution of the group and forming the basis for a discussion of species-forming. These are species in the making and give good examples of series diverging but little from each other and from the common ancestor. A discussion is also given of the correlation of the *Tropites subbullatus* zone and the classification of the Upper Triassic of California.

FAUNA OF THE IDAHO FORMATION

BY JOHN C. MERRIAM

(Abstract)

A very extensive series of sediments exposed in the valley of the Snake River, in southwestern Idaho, described by Cope as the Idaho formation, has been carefully studied and described by Lindgren. From this formation a mammalian fauna secured by Lindgren has been listed by Lucas and referred to the Pliocene.

The known list of mammals from the Idaho includes a number of forms which approach very closely in their stage of evolution to the Pleistocene of western North America, but differ specifically from all Pleistocene species. Such differences as appear are mainly in the direction of primitiveness. A number of other forms found in the Idaho fauna are distinctly of a Pliocene type. As nearly as can be judged, the mammalian fauna of the Idaho represents a Pliocene stage later than any other Pliocene fauna of the Pacific Coast and Great Basin regions, with possible exception of the Tulare Pliocene occurrence on the western border of the San Joaquin Valley.

OCCURRENCE OF A MARINE MIDDLE TERTIARY FAUNA ON THE WESTERN BORDER OF THE MOJAVE DESERT AREA

BY WALLACE GORDON

Read by J. C. Merriam.

FAUNA OF THE BAUTISTA CREEK BADLANDS

BY CHILDS FRICK

(Abstract)

During the fall of 1916 the posterior portion of a lower jaw of a fossil horse from the Bautista Creek badlands, near Hemet, California, came into the hands of Dr. J. C. Merriam through the kindness of Mr. J. C. Blackburn. Several weeks of systematic collecting at this locality has resulted in the gathering of other well preserved horse remains, some cervid material, including parts of the dentition, skull, and skeleton, as well as fragmentary evidence of an antelope smaller than *Capromeryx minor*, and of a small ground sloth.

The dentition of the horse is of primitive character and apparently indicates a new form. The other species likewise appear to be new, and all probably represent a new or imperfectly known stage in the faunal sequence from the late Pliocene to the early Pleistocene.

This fauna is particularly interesting in its geographic position between the marine beds of the Pacific and those of the Gulf.

OCCURRENCE OF THE SIPHONALIA SUTTERENSIS ZONE, THE UPPERMOST TEJON HORIZON IN THE OUTER COAST RANGES OF CALIFORNIA

BY ROY E. DICKERSON

(Abstract)

The uppermost horizon of the Tejon Eocene of California, the *Siphonalia sutterensis* zone, was described from the Eocene of Marysville Buttes and later recognized as occurring at Oroville, beneath the basalt of Oroville, South Table Mountain, at Ione, on the western flanks of the Sierra Nevada, and at Merced Falls. In the study of the Mount Diablo region, the Coalinga District, and the southern end of San Joaquin Valley, at the type locality of the Tejon group and at San Diego, this upper horizon was not recognized. The zone was placed as an uppermost phase on the basis of stage of evolution and its close connection with the *Balanophyllia variabilis* zone of the Mount Diablo region. A year ago Mr. Reginald Stoner discovered a locality in the Santa Susana Mountains, on Alliso Canyon, of Devil Creek, just beneath Miocene strata. The fossils from this locality represent a lower phase of the *Siphonalia sutterensis* zone and the fauna is essentially the same as the *Siphonalia sutterensis* zone of the Roseburg quadrangle, on Little River, near the confluence with the Umpqua. In the Simi Hills, a few miles away from the locality discovered by Mr. Stoner, the *Rimella simplex* zone of the Middle Tejon stage occurs. The general absence of this zone throughout most of the Coast Range region is probably due to extensive erosion during the interval between Upper Eocene and Oligocene time.

At the conclusion of the reading of papers the meeting adjourned and the members of the Paleontological Society attended a dinner of the Le Conte Club, at the Stanford Union.

On Saturday, April 7, at 10.45, the meeting was called to order by Dr. C. E. Weaver. The following papers were presented:

**CRETACEOUS AND TERTIARY STRATIGRAPHY OF THE WESTERN END OF THE
SANTA INEZ MOUNTAINS, SANTA BARBARA COUNTY, CALIFORNIA**

BY H. J. HAWLEY

(Abstract)

The western end of the Santa Inez Mountains is made up wholly of sedimentaries of Cretaceous and Tertiary age. The Cretaceous is represented by Chico sandstones, overlain unconformably by Tertiary sediments. The Tejon is the local representative of the Eocene period, and the fauna of this series shows a remarkable similarity to the fauna from the type Tejon. Lower Miocene, which may be divided into Vaqueros and Monterey, represents the latest period of deposition in this region.

**GEOLOGIC RANGE AND EVOLUTION OF THE MORE IMPORTANT PACIFIC
COAST ECHINOIDS**

BY W. S. W. KEW

(Abstract)

Geologic ranges of the more important echinoid genera of the Pacific coast are as follows: *Cidaris*, Eocene, with exception of one species in the Oligocene; *Strongylocentrotus*, Pliocene to Recent; *Scutella*, Upper Eocene to Pliocene, with greatest development in the Lower Miocene; *Dendraster*, dominant in the Pliocene and continuing to the Recent; *Astrodapsis*, confined to the Upper Miocene and Lower Pliocene.

Scutella, *Astrodapsis*, and *Dendraster* serve best to illustrate the lines of descent of echinoids on the Pacific coast. *Scutella* evolves along two main lines, that of the *S. coosensis*-*S. norrisi* group and that of the *S. merriami*-*S. blancoensis* group. *Astrodapsis*, derived from the *Scutellas*, acquires the characters of elevated petals and grooved interambulacral areas, which become more pronounced until the specialized *A. major* and *A. arnoldi* stages are reached. Following these stages the genus suddenly becomes extinct. *Dendraster*, also originating from the *Scutellas*, passes from the *D. gibbsi* type, with more or less thickened test and eccentric apical system, to the thin test and extreme apical eccentricity of *D. ashleyi* (Arnold), and finally to the recent *D. eccentricus* (Eschscholtz), with a less eccentric apical system.

**EVIDENCE IN SAN GORGONIO PASS, RIVERSIDE COUNTY, OF A LATE
PLIOCENE EXTENSION OF THE GULF OF LOWER CALIFORNIA**

BY F. E. VAUGHAN

(Abstract)

A small invertebrate fauna was collected in San Gorgonio Pass, 3 miles east of Millard Canyon. Several forms from this locality are the same as

species found by W. S. W. Kew at Carrizo Creek. The beds occurring at the latter locality are considered by T. W. Vaughan as not older than Lower Pliocene.

VAQUEROS FORMATION IN CALIFORNIA

BY W. F. LOEL

(Abstract)

The horizon markers and principal features show this division of the Lower Miocene to be a distinct and true formation, both faunally and lithologically.

*TERTIARY AND PLEISTOCENE FORMATIONS OF THE NORTH COAST OF PERU,
SOUTH AMERICA*

BY G. C. GESTER

(Abstract)

The Tertiary formations of the north coast of Peru are similar in many respects to the Tertiary formations of the west coast of North America. A comparison of the faunas shows many closely related species. An interesting feature of the north Peruvian coast is the elevated tableland, or "tablaza," which extends for several miles inland from the coast. The "tablaza beds" are richly fossiliferous and probably belong to the Pleistocene period.

*SYMPOSIUM ON CORRELATION OF OLIGOCENE FAUNAS AND FORMATIONS OF
THE PACIFIC COAST*

BY C. E. WEAVER, R. E. DICKERSON, AND B. L. CLARK

PALEOGEOGRAPHY OF THE OLIGOCENE OF WASHINGTON

BY CHARLES E. WEAVER

(Abstract)

Two Oligocene embayments occur in Washington. The northern embayment occupied approximately the area between the Olympic Mountains and Vancouver Island and extended into the Puget Sound Basin as far south as Seattle. The southern embayment existed in the present region of Gray's Harbor and extended as far south as the Cowlitz Valley, in the northern part of Cowlitz County. In the northern embayment there were deposited approximately 14,000 feet of sandstone and shale. In the southern embayment the deposits are 4,000 feet in thickness. The basal faunas in the southern embayment, as represented at Oakville, are the same as the basal faunas in the northern embayment at Port Discovery Bay, near Port Townsend, and also the basal beds on the south shore of Vancouver Island, which have been described as the Sooke Beds. In both the northern and southern embayments the strata above the Sooke Beds contain a fauna of subtropical character which has been designated the *Molopophorous lincolniensis* zone, the type locality of which is at Lincoln Creek, in Thurston County. In the northern embayment the Upper Oligocene

beds contain a colder water fauna, which has been designated as the *Actinopterygiens* zone. This fauna is absent in the southern embayment.

PALEONTOLOGY AND STRATIGRAPHY OF THE PORTER DIVISION OF THE OLIGOCENE IN WASHINGTON

BY KATHERINE E. VAN WINCKLE

(Abstract)

The report embodies the results of stratigraphic and faunal studies of the Porter division of the Oligocene of Washington at the type locality on Porter Creek. The formation consists predominantly of shaly sandstones and sandy shales having a thickness of 1,200 feet. These beds rest unconformably on Tejon basalts. From the lower portion of the section a marine invertebrate fauna of 20 species was obtained, while from the upper beds 30 species were secured. Twelve species occurring in the lower beds are common to those in the upper. The fauna at Porter has a closer similarity to that at Lincoln Creek than it has to the Blakely fauna at Restoration Point. It is possible that the beds at Porter can be correlated with those exposed at Lincoln Creek.

Read by C. E. Weaver.

FAUNAL ZONES OF THE OLIGOCENE

BY B. L. CLARK

CLIMATE AND ITS INFLUENCE ON OLIGOCENE FAUNAS OF THE PACIFIC COAST

BY ROY E. DICKERSON

At the conclusion of the reading of the papers the meeting adjourned

REGISTER OF MEMBERS AND VISITORS AT STANFORD MEETING, 1917

E. M. BUTTERWORTH	W. S. W. KEW
J. P. BUWALDA	W. F. LOEL
B. L. CLARK	J. C. MERRIAM
R. E. DICKERSON	J. O. NOMLAND
CHILDS FRICK	IDA OLDROYD
MRS. CHILDS FRICK	K. H. SCHILLING
G. C. GESTER	J. P. SMITH
H. GESTER	W. S. T. SMITH
H. J. HAWLEY	CHESTER STOCK
E. S. HEATH	C. M. WAGNER
A. R. KELLOGG	C. E. WEAVER

Proceedings of the Paleontological Society

PROCEEDINGS OF THE TWELFTH ANNUAL MEETING OF
THE PALEONTOLOGICAL SOCIETY, HELD AT CHICAGO,
ILLINOIS, DECEMBER 28-30, 1920.

R. S. BASSLER, SECRETARY

[Reprinted from the BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA,
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BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA

VOL. 32, PP. 119-156

MARCH 31, 1921

PROCEEDINGS OF THE PALEONTOLOGICAL SOCIETY

PROCEEDINGS OF THE TWELFTH ANNUAL MEETING OF
THE PALEONTOLOGICAL SOCIETY, HELD AT CHICAGO,
ILLINOIS, DECEMBER 28-30, 1920.¹

R. S. BASSLER, *Secretary*

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SESSION OF TUESDAY, DECEMBER 28

The first general session of the Society scheduled for 2 p. m. Tuesday, December 28, was postponed until Wednesday morning, so that the members could meet with the Fellows of the Geological Society of America for the reading of the stratigraphic and paleontologic papers forming Group B of that Society's program..

Tuesday evening the members met at Rosenwald Hall with the Geological Society of America, the Mineralogical Society, and the Society of Economic Geologists, to hear the addresses of I. C. White, retiring President of the Geological Society, and of C. K. Leith, retiring Vice-President of Section E, American Association for the Advancement of Science, following which the four societies participated in a joint smoker.

SESSION OF WEDNESDAY, DECEMBER 29

The twelfth annual meeting of the Society was called to order by President Loomis at 9.30 a. m., December 29, in Walker Museum of the University of Chicago. The report of the Council was presented by the Secretary as the first matter of business.

REPORT OF THE COUNCIL

To the Paleontological Society, in twelfth annual meeting assembled:

The meetings of the Council, as heretofore, have been limited to one following the last annual meeting and one immediately preceding the present session, all other business having been transacted by correspondence. The Council's administration of the Society's business for the twelfth year is presented in the following reports:

SECRETARY'S REPORT

To the Council of the Paleontological Society:

The proceedings of the eleventh annual meeting of the Society, held at Boston, Massachusetts, December 30-31, 1919, are printed in volume 31, pages 197-232, of the Bulletin of the Geological Society of America.

The Council's proposed nominations for officers and the announcement that the twelfth annual meeting of the Society would be held at Chicago, December 28-30, 1920, as the guest of the University of Chicago, was issued March 15, 1920.

The nomination of Dr. Arthur Hollick as representative of the Paleontological Society on the Board of Control of Botanical Abstracts to succeed Dr. F. H. Knowlton, whose term had expired, was approved by the Council.

Membership.—During the year the Society has lost three members by death: Mr. Walter R. Billings, of Ottawa, Ontario, nephew of E. Billings and, like his distinguished relative, a student of the invertebrates of the Lower Paleozoic rocks of Canada; Mr. Homer Hamlin, of Los Angeles, California, and Mr. Wilbur L. Moody, of Berkeley, California, both students of Pacific Coast paleontology and stratigraphy.

One member has resigned during the year, the election of fourteen new members has just been concluded, and five additional nominations are awaiting consideration at the present meeting. This year four of our members have been elected to fellowship in the Geological Society of America. The result of these various changes leaves the total number of members at the end of 1920 as 209.

Publications.—Besides the Proceedings, eight papers published by the Society in the Bulletin of the Geological Society of America have been distributed to the members during the course of the year.

Pacific Coast Section.—The tenth annual meeting of the Pacific Coast Section of the Paleontological Society was held at Seattle, Washington, June 18, 1920, in conjunction with the Cordilleran Section of the Geological Society of America, the two societies participating in the fourth annual meeting of the Pacific Division of the American Association for

the Advancement of Science. The meeting was called to order by Dr. E. L. Packard, in the Science Hall of the University of Washington, and nine papers on the paleontology and stratigraphy of the west coast were presented. As an item of business, it was moved and carried that the new officers of the Pacific Coast Section should be voted on by mail at a later date determined by the secretary.

The election of officers was held in October, 1920, with the following results:

President, E. L. PACKARD.
Vice-President, B. L. CLARK.
Secretary, CHESTER STOCK.

The minutes of this section are printed on pages 145 to 149 of this Bulletin.

Respectfully submitted,

R. S. BASSLER,
Secretary.

WASHINGTON, D. C., *December 27, 1920.*

TREASURER'S REPORT

To the Council of the Paleontological Society:

The Treasurer begs to submit the following report of the finances of the Society for the fiscal year ending December 24, 1920:

RECEIPTS

Cash on hand December 20, 1919.....	\$623.76
Membership fee.....	276.30
Interest, Connecticut Savings Bank.....	23.58
	<hr/> \$923.64

EXPENDITURES

Treasurer's office:	
Treasurer's allowance.....	\$25.00
Printing and postage.....	16.50
	<hr/> \$41.50
Secretary's office:	
Secretary's allowance.....	\$50.00
Office expenses.....	68.52
Clerical help.....	25.00
	<hr/> 143.52
Geological Society of America:	
For printing separates.....	54.94
Pacific Coast Section:	
Assessment for the American Association for the Advancement of Science.....	15.00
	<hr/> 254.96
Balance on hand December 24, 1920.....	<hr/> \$668.68

Net increase in funds.....		\$44.92
Outstanding dues (1919), 2.....	\$6.00	
Outstanding dues (1920), 3.....	9.00	
		<hr/> \$15.00

Respectfully submitted,

RICHARD S. LULL,
Treasurer.

NEW HAVEN, CONNECTICUT, *December 24, 1920.*

APPOINTMENT OF AUDITING COMMITTEE

Following the reading of the Treasurer's report, President Loomis appointed Messrs. Stuart Weller and A. W. Slocum as a committee to audit the accounts.

ELECTION OF OFFICERS AND MEMBERS

The result of the ballots for the election of officers for 1921 and of new members was then announced as follows:

OFFICERS FOR 1921

President:

T. W. STANTON, Washington, D. C.

First Vice-President:

C. K. SWARTZ, Baltimore, Maryland

Second Vice-President:

W. J. SINCLAIR, Princeton, New Jersey

Third Vice-President:

ARTHUR HOLLICK, New York City

Secretary:

R. S. BASSLER, Washington, D. C.

Treasurer:

RICHARD S. LULL, New Haven, Connecticut

Editor:

WALTER GRANGER, New York City

NEW MEMBERS FOR 1921

PERRY A. GLICK, 502 East Springfield Street, Champaign, Ill.
LEONARD WILSHIER HENRY, Morton Street, Portersville, Calif.
RAYMOND R. HIBBARD, 450 Carlton Street, Buffalo, N. Y.
HENRY V. HOWE, 1514 Alder Street, Eugene, Oregon.
DOROTHY B. KEMPER, 2527 Benevenue Street, Berkeley, Calif.
GEORGE FREDERICK MATTHEW, 115 Carmarthen Street, St. John, N. B.
FLORENCE EMMA MOSES, 5424 Claremont Avenue, Oakland, Calif.
ADOLF CARL NOÉ, University of Chicago, Chicago, Ill.
ESTHER E. RICHARDS, Rio Bravo Oil Company, Southern Pacific Building,
Houston, Texas.
RICHARD JOEL RUSSELL, 2412 Piedmont Avenue, Berkeley, Calif.
ARTHUR WARE SLOCOM, Walker Museum, University of Chicago, Chicago, Ill.
FRANK PETER STRICKLAND, JR., 640 Oakland Street, Kansas City, Mo.
PARKER DAVIES TRASK, 1502 Alice Street, Oakland, Calif.
ALFRED OSWALD WOODFORD, Pomona College, Claremont, Calif.

AMENDMENT TO THE CONSTITUTION

The Secretary then announced the result of the balloting regarding the proposed amendment of Article III, section 5, of the Constitution, namely: "Fellows, Members, and Patrons are entitled to vote, but only Fellows are eligible to office in this Society," be amended so as to require only that the President of the Society be a Fellow. The amendment was lost, as less than one-half of the Fellows voted favorably, instead of the necessary three-fourths.

NEW NOMINATIONS AND ELECTION TO MEMBERSHIP

The President then directed the Secretary to read the list of new nominations, which had arrived too late for the printed ballot and which, having received the approval of the Council, were under consideration for election:

PAUL C. MILLER, Assistant Curator of Paleontology, Walker Museum, University of Chicago. Proposed by E. S. Riggs and F. B. Loomis.
RICHARD NEWMAN NELSON, graduate student, University of California. B. A. University of Oregon (1919). Proposed by Chester Stock and B. L. Clark.
NORMAN E. NELSON, 116 East Eighth Street, Fort Worth, Texas. Student of Cretaceous paleontology and stratigraphy. Proposed by E. O. Ulrich and R. S. Bassler.
WILL McCLAIN WINTON, Professor of Biology and Geology, Texas Christian University, Fort Worth, Texas. M. S., Vanderbilt University (1908). Proposed by E. O. Ulrich and R. S. Bassler.
OTTO T. WALTER, Research assistant in paleontology, University of Iowa. M. S., University of Iowa (1917). Proposed by A. O. Thomas and R. S. Bassler.

Upon motion by Professor Weller, it was voted that the By-Laws be suspended and that the Secretary cast the vote of the Society for the election to membership of these five new nominees.

ELECTION OF CORRESPONDENT

President Loomis then reported that the Council favored the election as Correspondent of Monsieur Ferdinand Canu, 18 Rue du Peintre Lebrun, Versailles, France, in view of his researches on paleogeography and his various monographs and essays on the fossil bryozoa of both Europe and America, his work on the latter culminating in the two quarto volumes forming Bulletin 106, U. S. National Museum, entitled "North American Early Tertiary Bryozoa." Monsieur Canu's election followed by unanimous vote.

With the completion of the business meeting, the Society proceeded, in general session, with President Loomis in the chair, to the reading of papers.

PRESENTATION OF PAPERS

The first paper of the session, presented by the author and illustrated by lantern slides, gave the results of ten years of exhibition work in paleontology at the New National Museum; discussion by Messrs. Moore and Weller.

PALEONTOLOGICAL EXHIBITS AT THE U. S. NATIONAL MUSEUM

BY E. S. BASSLER

(Abstract)

As this meeting marks the end of the first decade of exhibition in the New National Museum, a report of progress seemed appropriate. The general difficulty of preparing interesting exhibits of fossil remains is increased in the National Museum by the fact that the interest must be national and not local. The methods of obtaining this result will be explained by lantern slides illustrating the three main halls of paleontology and by samples of the descriptive labels employed. Each hall is devoted to a special branch of paleontology, namely, the vertebrate, invertebrate, and plant divisions, and the exhibits in each are arranged for study by the biologist, geologist, and the general public. For the first, there is a biological series, in which the evolution of the various classes of organisms is the essential theme; for the geologist, the characteristic fossils and rocks of each formation are arranged chronologically and accompanied by a long structure section across the continent; for the general public, large exhibits illustrating subjects which include matters of geological history, in addition to the display of fossils and their occurrence in the rocks, are displayed, usually on bases open to inspection by the visitor. In this latter series a fossil coral reef, a large block showing an unconformity, sea beaches of various geological periods, and similar subjects are included.

An instructive paper on Paleozoic cephalopods, illustrated by diagrams and read, in the absence of the author, by President Loomis, brought forth a discussion by Messrs. Foerste, Chadwick, and Bassler.

OBSERVATIONS ON THE MODE OF LIFE OF PRIMITIVE CEPHALOPODS

BY R. RUEDEMANN

(Abstract)

The purpose of this paper is to record some new observations on the life habits of the earlier cephalopods based on specimens of *Orthoceras* from the Trenton limestone and Guelph dolomite of New York, retaining color lines on one side, and others from the Utica and Lorraine shales of New York, showing sexual differences in size, shape, and surface sculpture.

The Secretary then presented for the author, in his absence, an account of the wonderful anatomical structures preserved in the Middle Cambrian Burgess shale branchiopod crustacea found near Field, British Columbia. Illustrated by lantern slides and specimens.

ANATOMY OF MIDDLE CAMBRIAN CRUSTACEA

BY CHARLES D. WALCOTT

(Abstract)

A presentation of the appendages and internal anatomy of the three Middle Cambrian branchiopod genera, *Waptia*, *Narwia*, and *Burgessia*, preliminary to a more detailed work to be issued in the near future by the Smithsonian Institution.

The following papers were read by title:

*AMERICAN SPECIES OF THE GENUS SCHWAGERINA AND THEIR
STRATIGRAPHIC SIGNIFICANCE*

BY J. W. REEDE

*GRAPTOLITE LOCALITIES OF WESTERN NORTH AMERICA, WITH DESCRIPTION
OF TWO NEW FORMATION NAMES*

BY L. D. BURLING

(Abstract)

The greater part of the paper is taken up with summaries and correlations of the available published information with reference to the twelve known graptolite localities in western North America.

Three new graptolite localities are described for western North America, all in the Desert ranges of Utah, and reported on by Ulrich, whose reports are copied.

Additional stratigraphic data are presented regarding two of the twelve known localities: Glenogle (British Columbia) and the Yukon-Alaska boundary. Regarding the former (Glenogle) this paper corrects the accepted reference of the Glenogle graptolites to "Kicking Horse Pass." It regards and discusses the discovery of fossils below, and makes a correction in the stratigraphy of the beds above, the graptolite shales, for which it proposes the formational name Glenogle shales. The beds above are shown to be of Richmond age, the first recorded instance of Richmond beds west of Lake Winnipeg and north of the Canadian boundary. Regarding the latter (Yukon-Alaska boundary) this paper lists four new localities in the general vicinity of the one previously known and presents new light on the stratigraphy of the graptolite-bearing beds, giving a section of the Paleozoic beds south of the Tatonduk River and defining one new formation, the Tatonduk shales. These collections have all been reported on by Doctor Ruedemann, whose reports are copied. There is also recorded a slight change in the recorded localities for *Dicranograptus nicholsoni whitianus* (Miller).

The bearing of the data presented on such questions as the number of graptolite horizons in the West, their origin and dispersal, is discussed and the conclusions drawn that there appear to be several horizons, and that the main channels of communication probably opened to the north.

The next paper was read by title.

NEW KIND OF TYPE SPECIMEN

BY E. L. TBOXELL

The next paper, illustrated by lantern slides and dealing with several Upper Cambrian trilobites of Iowa, was presented by the author and discussed by Messrs. Weller and Chadwick.

UPPER CAMBRIAN TRILOBITES

BY O. T. WALTER

(Abstract)

As far as now known, only three trilobites have been reported from the Upper Cambrian of Iowa, namely, *Dikelocephalus minnesotensis* Owen, *Illanurus quadratus* Hall, and a new species of *Illanurus*, here designated as *Illanurus calvini*. These three species are found associated in the Saint Lawrence limestone near Lansing, Allamakee County, Iowa. *Illanurus quadratus* Hall occurs somewhat doubtfully at this place, while *Illanurus calvini* is found in abundance and in association with *Dikelocephalus minnesotensis*. As in the case with the latter, the new *Illanurus* is more or less dismembered; a restoration brings out several interesting features. The first reference made to *I. calvini* was by the late Prof. S. Calvin in the Iowa Geological Survey, volume IV, page 58. This species differs notably from *I. quadratus* in the presence of long postero-lateral extensions of the fixed cheeks.

Some notes on a trilobite from the province of Szechuan, west China, are also presented.

A stratigraphic paper giving a detailed classification and description of the Niagaran rocks of northern Michigan was then read by the author and brought forth discussion from Messrs. Twenhofel, Foerste, and M. Y. Williams.

NIAGARAN ROCKS OF THE NORTHERN PENINSULA OF MICHIGAN

BY G. M. EHLERS¹

(Abstract)

The Niagaran rocks of the northern peninsula of Michigan, with the exception of those exposed in the Limestone Mountain outlier in Houghton County, are at or near the surface of a wide belt of land bordering the northern shores of Lakes Huron and Michigan. These rocks consist almost entirely of limestones and dolomites, are remarkable for their continuity from Wisconsin to Ontario, and have a maximum thickness of nearly 1,000 feet.

A classification of these rocks is proposed in which the strata, beginning at the base, are grouped under the names Mayville, Burnt Bluff, Manistique, and Racine formations.

The Mayville formation is a northeastward continuation of the Mayville beds of Wisconsin. The base of the formation in Michigan has not been seen; the top is provisionally placed at the top of a yellowish gray dolomite containing numerous remains of the brachiopod named *Virgiana mayvillensis* by Savage. This horizon extends eastward as far as Manitoulin and Fitzwilliam islands, Ontario, in which regions it is included in the upper part of the Cataract formation by M. Y. Williams. It is thought that this horizon is younger than Cataract, and that the entire Mayville formation is of Niagaran age instead of Alexandrian, as stated by Savage. The *Virgiana mayvillensis* dolomite of the Mayville probably represents the same stratigraphic horizon as the *Virgiana (Conchidium) decussata* beds of Limestone Mountain, Michigan, of the Hudson Bay region, and of the Stonewall limestone of Manitoba.

The overlying Burnt Bluff formation seems to be limited above by a disconformity, and with little doubt is a northeastward extension of the Byron, Transition, and lower part of the Lower Coral Beds of Wisconsin. Certain beds of the formation—that is, the Fiborn limestone and upper part of the Hendricks series of R. A. Smith's tentative classification—are regarded by Savage and Crooks as being of Alexandrian age. The Burnt Bluff formation, which includes these beds, is thought by the writer to be of Niagaran age. The formation without doubt is equivalent to the Severn River limestone of the Hudson Bay region and the Wabi formation of the Lake Timiskaming region.

The Manistique formation is a northeastward extension of the Upper Coral Beds and the upper part of the Lower Coral Beds of Wisconsin. The well known coral horizon of this formation, which also occurs in the Upper Coral Beds of Wisconsin, is represented by the Fossil Hill coral horizon of the Lockport formation of Manitoulin Island and by a similar horizon in the Lockport of the Lake Timiskaming region.

¹ Introduced by E. C. Case.

The Racine formation of Michigan is an extension of the formation in Wisconsin which James Hall designated as the Racine limestone. The formations in Ontario, which are thought to be included in the Racine, are the Guelph and the thick-bedded, white to very light gray dolomite at the top of the Lockport of Cockburn and Manitoulin islands.

Following Mr. Ehler's paper was an account by Dr. Roy L. Moodie of his recent researches in paleopathology. This paper, which was illustrated by lantern slides, was supplemented by a demonstration later of specimens and microscopic preparations in an adjoining laboratory to those interested.

STATUS OF OUR KNOWLEDGE OF MESOZOIC PATHOLOGY

BY ROY L. MOODIE

(Abstract)

This paper discusses the degree of progress made during the Mesozoic. Fifteen pathological results, classified under the following five headings, will be described: 1, Arthritides; 2, Tumors; 3, Necroses; 4, Hyperostoses; 5, Fractures.

An account of the small fossils obtained by washing the Devonian shales of Iowa followed, and was presented by the author, with illustrations by lantern slides.

SMALL FOSSILS FROM THE LIME CREEK SHALES

BY A. O. THOMAS

(Abstract)

At the last meeting of the Paleontological Society the writer reported the finding of dissociated plates, spines, and parts of the lantern of three Devonian sea-urchins from the Lime Creek shales of Iowa. Since then quantities of the marly shales in which these occur have been screened and then washed through a series of fine-meshed sieves with the purpose of trying to find ambulacral plates and other small parts of the dissociated tests. In this manner many of the small parts of the echinoids were secured and, in addition, some ostracod valves and a few foraminifera. This led to more screening and washing from several horizons with excellent results. Bolting cloth was used to catch some of the very finest material. The small forms were then sorted out of the dried screenings under a Zeiss binocular.

In the coarser siftings examined occur a few of the larger forms mentioned below; also some juvenile brachiopods, fragments of shells and bryozoa, bits of coral, pieces of spines, and plates of sea-urchins, and various other broken organic remains.

The finer siftings, however, yield the best results. At several horizons the commonest fossils are the spirally marked, spheroidal bodies of doubtful affinity.

ties, known as *Calciophara robusta* Williamson. They occur by the score, and lumps of the shale may be found in which large numbers of them are massed together. A few have been isolated on which the spiral lines are double.

Among the foraminifera a rotaline form is fairly common. It seems to belong to a new genus. *Lagena* and *Saccamina* are rare; the latter gives evidence of occurring in chains, as illustrated by Brady and others. A *Globigerina*-like species is found sparingly at one or two horizons. Minute tetractinellid spicules represent the sponges.

Conodont teeth referable to the genus *Polygnathus* occur. These microscopic translucent worm remains are beautifully preserved and are among the smallest forms recovered. Small, slender, annulated shells of *Tentaculites* are common in nearly every pan of the marl. Their exquisite hyaline tips are preserved in many cases. Some of these are doubtless the young of a new species of *Tentaculites* from the same beds and which reach a length of five millimeters or more.

The screenings are rich also in shells of tiny ostracods. Some of the genera are abundant and are represented by more than one species; a few, notably *Entomis*, are very rare. The commonest genera are *Bairdia*, *Kirkbyina*, *Bythocypris*, *Cypridina*, and *Beyrichia*, while there are several forms which have not been generically determined.

The meeting then adjourned for luncheon.

PRESIDENTIAL ADDRESS

At 2 p. m. the Society met to hear the address of the retiring President of the Paleontological Society, entitled

ORIGIN OF THE SOUTH AMERICAN FAUNAS

PRESIDENTIAL ADDRESS BY F. B. LOOMIS

Following this address, the reading of the papers prepared for the symposium and arranged for the meeting was taken up.

SYMPOSIUM ON CRITERIA AND METHODS EMPLOYED IN PALEONTOLOGIC RESEARCH

CRITERIA FOR THE DETERMINATION OF THE CLIMATIC ENVIRONMENT OF EXTINCT ANIMALS

BY E. C. CASE

CRITERIA FOR DETERMINATION OF CLIMATE BY MEANS OF FOSSIL PLANTS

BY F. H. KNOWLTON

METHODS OF DETERMINING THE RELATIONSHIPS OF MARINE INVERTEBRATE FOSSIL FAUNAS

BY CHARLES SCHUCHERT

CRITERIA FOR SPECIES, PHYLOGENIES, AND FAUNAS OF TRILOBITES

BY P. E. RAYMOND

AGE DETERMINATION OF FAUNAS

BY E. O. ULRICH

METHODS OF CREATING POPULAR INTEREST IN EXHIBITS OF FOSSILS

BY E. S. BIGGS

Upon the completion of the symposium, the reading of papers on the regular program was resumed.

PRESENTATION OF PAPERS

In the absence of the author, the following was read by the Secretary:

DECREASING SALINITY OF THE PLEISTOCENE CHAMPLAIN SEA GOING SOUTHWARD, AS SHOWN BY THE CHARACTER OF THE FAUNA, WITH A BRIEF DISCUSSION OF THE PLEISTOCENE FAUNA OF THE HUDSON VALLEY AND ITS SIGNIFICANCE¹

BY WINIFRED GOLDRING

(Abstract)

Recent collecting in the Pleistocene deposits of the Champlain and Saint Lawrence valleys has called attention to the fact that going southward there is a marked change in the fauna, similar to that seen in the Baltic Sea today. Careful study of this fauna and comparison with the conditions found in the Baltic and elsewhere has led to the conclusion that the character of the Champlain fauna is due in large part at least to decreasing salinity southward in the waters of that time.

The Baltic Sea shows a very striking decrease in salinity eastward and, in a large way, the responses of the fauna to it. As the salinity of the water decreases from that normal for sea-water, the fauna changes from one typically marine to one in which only a few marine groups are represented and finally to a fresh-water fauna. Another striking change has been noted in the character of the Baltic fauna which may likewise be correlated with the variation in salinity: As the stenohaline forms disappear entirely, euryhaline forms become dwarfed. Modifications due to changes in the salt content of water are not confined to invertebrates alone. The dwarfing of fishes in the Baltic has been noted above; also the fishes of the Black Sea in their paucity of specific forms (compared with those of the Mediterranean) and marvelously great number of individuals are very indicative of the estuarine character of its waters.

A careful list, with localities, has been compiled of the Pleistocene invertebrate species collected by the writer and also all those reported by others in various publications, and these have been tabulated to show the distribution of the species from the sea (Labrador) to the southernmost locality (two miles

¹ This paper will appear in full in a New York State Museum Bulletin.

south of Crown Point station) from which they have been collected in the Champlain area.

Comparisons have been made of specimens of the Pleistocene species of the Champlain area with those of Canada and with recent representatives, and it has been found that the Champlain fauna is a dwarf fauna.

The Pleistocene fauna of the Hudson Valley is briefly considered. No fossils have been reported from these Pleistocene deposits south of Croton Point, either from the New York or New Jersey shores. The most northern point at which Pleistocene fossils have been reported from the Hudson Valley is at Storm King, 50 miles above New York, where was found, in drilling a series of holes across the Hudson bed, a fauna represented by two species living at present along the New England and New Jersey coasts, *Mulinia lateralis* and *Trivia trivittata*. This has been shown by Shimer to be a dwarf fauna. At Croton Point, about 20 miles farther south, occurs a large Pleistocene oyster bed in which are found the following marine forms: *Mya arenaria*, *Modiola demissus*, *Mulinia lateralis*, and *Alectrion* (= *Nassa*) *obsoleta*. The largest specimen of *Mulinia lateralis* here is larger than the large specimens from Storm King, but smaller than the recent shore forms, as one might expect in waters of decreasing salinity. Salt-water organisms at present pass up the Hudson only to the Highlands, though its waters are brackish as far north as Poughkeepsie.

The data for the Hudson Valley Pleistocene fauna are meager, but the evidence obtained, however, seems to lead to conclusions similar to those arrived at for the Champlain area. The waters of the Pleistocene Hudson estuary were so freshened going northward that (1) only a few marine forms were able to advance into these waters at all; (2) so far as present knowledge goes, only two species reached as far up as Storm King, 50 miles above New York, and none have been reported north of this locality; (3) the two species found at Storm King represent a dwarf fauna, one of them, *Mulinia lateralis*, occurring in a dwarfed condition (less so, however) at Croton Point, about 20 miles farther south.

It is recognized that clay deposited in fresh water shows a laminated character not found in similar deposits in very brackish or salt water. The laminated character of the Hudson Valley clays, seen as far south as Haverstraw, and the absence of this peculiar laminated character in any of the localities in the Champlain area where marine fossils were found verifies what has already been indicated by the distribution and character of the faunas of these areas: (1) that the Pleistocene waters of the Hudson Valley were fresh or practically fresh north of Storm King; (2) that the Champlain Sea extended southward in a brackish condition, gradually freshened to a point a few miles south of Crown Point station, and that south of this area its waters were fresh or practically fresh.

At 5.30 the Society adjourned until the following day.

Wednesday evening at 7 o'clock the members attended the annual dinner of the Geological Society of America and affiliated societies, at the Chicago Beach Hotel.

SESSION OF THURSDAY, DECEMBER 30

Thursday morning at 9.30 the Society met in general session, with President Loomis presiding.

REPORT OF THE AUDITING COMMITTEE

The report of the Auditing Committee was announced, attesting to the correctness of the Treasurer's accounts; whereupon it was voted by the Society that the report be accepted.

PRESENTATION OF PAPERS

The first paper on the program was an account of some interesting plant remains, illustrated by lantern slides and presented by the author.

CYCADLIKE LEAVES FROM THE PERMIAN OF TEXAS

BY ADOLF C. NOÉ

(Abstract)

Among a number of fossil plants collected in 1920 in Baylor County, Texas, by Mr. Paul Miller, Assistant Curator of Walker Museum, University of Chicago, are a number of cycadlike leaves. The purpose of this paper is to describe and illustrate these leaves, which had been found in a bed of Permian shale, and to compare them with similar leaves which Prof. G. R. Wieland has described from the Lias of Mexico and with other early cycadeoid impressions. Their main interest lies in the fact that they are among the earliest known representatives of Cycadophytes. Since no seeds were discovered in connection with these leaves, it is impossible to determine whether they belong to true Cycads, or *Williamsonias*, or *Cycadofilicales*, but the fronds strongly resemble those of true Cycads.

The three following papers on paleobotany were then read by title:

GENUS SEQUOIA IN THE MESOZOIC

BY E. C. JEFFREY

(Abstract)

The author has had the opportunity of examining for the first time large quantities of twigs, with structure preserved, belonging to the genus *Sequoia* as recognized in the American Cretaceous. It is clear, from the evidence here furnished, that the organization of these twigs has little in common with that of our living *Sequoias* and their allies. They in fact are the branches of *Araucarian* conifers—a possibility long ago suggested by Saporta on the basis of their external habit. A recent suggestion that these twigs are wrongly identified has been withdrawn by its author, who now maintains that the

anatomical evidence does not prove their Araucarian affinities. Work carried out under the author's supervision makes it clear that true remains of the genus *Sequoia* do not make their appearance till the upper members of the Laramie series are reached. It will be necessary in the future to distinguish between the true *Sequoias* of the later Laramie and of the Tertiary and those Araucarian forms masquerading as *Sequoias* in the earlier Cretaceous and the Jurassic.

GENUS *ARAUCARIOXYLON* IN THE AMERICAN CRETACEOUS

BY E. C. JEFFREY

(Abstract)

The author and his students have collected material of *Araucarioxylon* from numerous localities and geological horizons of the North American Cretaceous, which supply reasons for modifications in our views as to the origin of the genus. It is generally assumed that the genus *Araucarioxylon* definitely connects the Araucarian conifers of the present epoch with the Cordaitales of the Paleozoic. The structure of woods in the American Cretaceous lends little support to that opinion, since they are less like the wood of *Cordaites* than are the woods of *Araucaria* and *Agathis*. The woods of the *Araucarioxylon* type in our deposits have the organization of *Cupressinoxyla* and the earlier annual rings of stems lack the *Araucarioxylon*-pitting. It is assumed from these data that the living Araucarian conifers are not closely related to the Cordaitales, but rather to a complex from which the Abietinæ or Pine family has taken origin. The roots of the living genera of the Araucarinæ are organized largely as is the stem of their Cretaceous ancestors.

CUPRESSINOXYLA OF THE MESOZOIC

BY E. C. JEFFREY

(Abstract)

The genus *Cupressinoxylon*, established many years ago, is of wide occurrence in the Jurassic and Cretaceous. It is generally assumed that woods of this type are to be referred to the Cupressinæ, Taxodinæ, or Podocarpinæ. The intention of the present communication is to show that many such woods are of Araucarian affinities. In a number of instances Araucarian pitting can be observed in such woods, while in others more refined criteria of Araucarian affinities have to be employed. Evidence is supplied on the one hand of the character of the ancestors of these Araucarian *Cupressinoxyla* and proof is furnished on the other of their being the ancestral types from which the living Araucarinæ have been derived. The genus *Cupressinoxylon* is formed as a response to marked seasonal variations of temperature and evidence is furnished for this conclusion.

An instructive presentation, illustrated by lantern slides and specimens, of a new reptilian suborder followed:

**DESMATOSUCHUS SUPRENSIS FROM THE DOCKUM TRIASSIC BEDS OF
WESTERN TEXAS**

BY E. C. CASE

(Abstract)

Desmatosuchus represents a new suborder of phytosauroid reptiles. The skull is characterized by the presence of a single temporal opening, the lack of a parietal foramen, a large antorbital opening, lateral nares, and a much reduced quadrate.¹ The vertebral column is essentially phytosaurian in character; very little of the limb bones or girdles was found. The back was covered by an armor, consisting of four rows of plates, which extended from the skull to the extremity of the tail. The outer row of plates carried sharp spines, which were larger in the cervical region. The fifth pair of outer plates carried enormously developed spines, nearly eighteen inches in length, which curved outward and forward.

The condition of the skull permitted a plastic cast to be made of the endocranial region. This shows the brain to have been relatively very small compared to the size of the animal. There was hardly any expansion of the cerebral lobes; the hypophysis is very large, and there is a smaller epiphysis or paraphysis with lateral processes. The position and size of the optic region and the location of the various cranial nerves are clearly shown on the cast.

In the absence of their authors, four papers dealing with fossil vertebrates were then read by title:

EVOLUTION, PHYLOGENY, AND CLASSIFICATION OF THE PROBOSCIDEA

BY HENRY FAIRFIELD OSBORN

CLASSIFICATION OF THE REPTILES

BY W. K. GREGORY

JURASSIC FISHES COLLECTED BY BARNUM BROWN IN CUBA

BY W. K. GREGORY

RELATIONSHIP OF THE GREAT BASIN AND GREAT PLAINS FAUNAS

BY E. L. TROXELL

An outline of paleobotanic work in progress on the Tertiary rocks of the West was presented by the author under the title

¹ A preliminary description of the skull and armor appeared in the *Journal of Geology*, vol. xxviii, no. 6, 1920.

PRELIMINARY NOTES ON RECENT TERTIARY COLLECTIONS IN THE WEST

BY RALPH W. CHANEY

(Abstract)

Collections of fossil plants were made during the past summer under the auspices of the University of California. In the John Day Basin material was secured from three horizons, in which some new species are represented; several new localities were discovered, including one at the type locality of the Mascall formation, where the flora resembles that previously secured from the Mascall, but contains a number of forms which indicate a swamp habitat. A collection from The Dalles group is of particular interest, since few fossils have been previously secured from this formation. The modern aspect of the leaves of this flora suggests its Pliocene or Pleistocene age. In the Sierras the Auriferous Gravels were visited, and limited collections made; these will be supplemented by collections during the coming field season, which will, it is hoped, establish the age or ages of the various gravel deposits.

The final paper on the program was given by President Loomis, who presented a discussion of the Lower Harrison Oreodonts, and especially the criteria for the determination of species and genera, under the title

LOWER HARRISON OREODONTS

BY F. B. LOOMIS

At 11.30 a. m. the Society adjourned.

Under the leadership of E. S. Riggs, the members then had the pleasure of a visit to the Field Museum, where several hours were spent in viewing the new building and in studying the exhibition collections and their installation.

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STAUFFER, CLINTON R., University of Minnesota, Minneapolis, Minn.
STEPHENSON, L. W., U. S. Geological Survey, Washington, D. C.
STERNBERG, CHARLES H., Balboa Park, San Diego, Calif.
STOCK, CHESTER, 492 Seventh Street, San Francisco, Calif.
STOVER, REGINALD C., Standard Oil Building, San Francisco, Calif.
SWARTZ, CHARLES K., Johns Hopkins University, Baltimore, Md.
TALBOT, MIGNON, Mt. Holyoke College, South Hadley, Mass.
TELLER, EDGAR E., 305 Ellicott Street, Buffalo, N. Y.
THOMAS, A. O., Department of Geology, University of Iowa, Iowa City, Iowa.
THOMPSON, ALBERT, American Museum of Natural History, New York City.
THORPE, MALCOLM R., Peabody Museum, New Haven, Conn.
TROXELL, EDWARD L., Osborn Botanical Laboratory, New Haven, Conn.
TWHENHOFEL, WILLIAM H., University of Wisconsin, Madison, Wis.
TWITCHELL, M. W., Geological Survey of New Jersey, Trenton, N. J.
ULRICH, EDWARD O., U. S. Geological Survey, Washington, D. C.
UNGER, CLAUDE E., Pottsville, Pa.
VAN DELOO, JACOB, Education Building, Albany, N. Y.
VAN INGEN, GILBERT, Princeton University, Princeton, N. J.
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VAN WINKLE, KATHERINE E. H., 126 Kelvin Place, Ithaca, N. Y.
VAUGHAN, T. WAYLAND, U. S. Geological Survey, Washington, D. C.
VOGDEN, ANTHONY W., 2425 First Street, San Diego, Calif.
WAGNER, CARROLL MARSHALL, 2520 Wilshire Building, Los Angeles, Calif.
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WHITE, DAVID, U. S. Geological Survey, Washington, D. C.
WHITTAKER, EDWARD J., Geological Survey of Canada, Ottawa, Canada.
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WILSON, ALICE E., Victoria Memorial Museum, Ottawa, Canada.
WILSON, HERRICK E., 224 West College Street, Oberlin, Ohio.
WOODRING, WENDELL P., U. S. Geological Survey, Washington, D. C.

CORRESPONDENT DECEASED

KOKEN, E., died November 24, 1912.

MEMBERS DECEASED

BARRELL, JOSEPH, died May 4, 1919.
BILLINGS, WALTER R., died March 1, 1920.
CALVIN, SAMUEL, died April 17, 1911.
CLARK, WILLIAM B., died July 27, 1917.

DERBY, ORVILLE A., died November 27, 1915.
EASTMAN, CHARLES R., died September 27, 1918.
FONTAINE, WILLIAM M., died April 30, 1913.
GILL, THEODORE N., died September 25, 1914.
GORDON, ROBERT H., died May 10, 1910.
HAMLIN, HOMER, died in July, 1920.
HARPER, GEORGE W., died August 19, 1918.
HAWVER, J. C., died May 15, 1914.
LAMBE, LAWRENCE M., died March 12, 1919.
LYON, VICTOR W., died August 17, 1919.
MOODY, W. L., died October 9, 1920.
PROSSER, C. S., died September 11, 1918.
SEELY, HENRY M., died May 4, 1917.
WARING, CLARENCE A., died November 4, 1918.
WILLIAMS, HENRY S., died July 31, 1918.
WILLISTON, SAMUEL W., died August 30, 1918.

MEMBERS-ELECT

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HENRY, LEONARD WILSHIER, Morton Street, Portersville, Calif.
HIBBARD, RAYMOND R., 450 Carlton Street, Buffalo, New York.
HOWE, HENRY V., 1514 Alder Street, Eugene, Oregon.
KEMPER, DOROTHY B., 2527 Benvenue Street, Berkeley, Calif.
MATTHEW, GEORGE FREDERICK, 115 Carmarthen Street, St. John, N. B.
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MOSES, FLORENCE EMMA, 5424 Claremont Avenue, Oakland, Calif.
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NELSON, RICHARD N., 2237 Durant Avenue, Berkeley, Calif.
NOÉ, ADOLF CARL, University of Chicago, Chicago, Ill.
RICHARDS, ESTHER E., Rio Bravo Oil Company, Southern Pacific Building,
Houston, Texas.
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STRICKLAND, FRANK PETER, JR., 640 Oakland Street, Kansas City, Mo.
TRASK, PARKER DAVIES, 1502 Alice Street, Oakland, Calif.
WALTER, OTTO F., 421 Reynolds Street, Iowa City, Iowa.
WINTON, W. M., Texas Christian University, Fort Worth, Texas.
WOODFORD, ALFRED OSWALD, Pomona College, Claremont, Calif.

MINUTES OF THE TENTH ANNUAL MEETING OF THE PACIFIC COAST
SECTION OF THE PALEONTOLOGICAL SOCIETYBY CHESTER STOCK, *Secretary*

The tenth annual meeting of the Pacific Coast Section of the Paleontological Society was held in conjunction with the Cordilleran Section, Geological Society of America, at Seattle, Washington, June 18, 1920. The societies participated in the fourth annual meeting of the Pacific Division, American Association for the Advancement of Science.

The meeting was called to order by Dr. E. L. Packard in the Science Hall of the University of Washington.

As an item of business, it was moved and carried that the new officers of the Paleontological Society should be voted on by mail at a later date determined by the Secretary.

READING OF PALEONTOLOGICAL PAPERS

The following paleontological and geological papers were then read:

*A STUDY OF THE FAUNA AND STRATIGRAPHY OF THE BRIONES FORMATION
OF MIDDLE CALIFORNIA*

BY PARKER DAVIES TRASK

(Abstract)

The Briones was formerly regarded as a part of the Monterey series (Lower and Middle Miocene), but the results of recent work have indicated that it is probably the lowest part of San Pablo series (Upper Miocene). The Briones deposits are found in an area of some 50 miles radius in the vicinity of San Francisco. Its sediments are chiefly sandstones, with some shales intercalated in the upper part of the formation. The thickness of the Briones varies from 500 to 2,300 feet.

There is no apparent difference in dip and strike between the Briones and the formations above and below, but there is usually a marked lithologic change, and irregular contacts with Pholas borings have been found between it and the over and under lying formations.

A study of the faunal evidence indicates a closer relation to the San Pablo than to the Monterey. Out of 70 determinable species found in the Briones, 11, or 15 per cent, extend into the Monterey, but only one of these 11 species is peculiar to these two formations, while 39 species, or 56 per cent, occur in the San Pablo, of which 19 species are peculiar to the Briones and the San Pablo. A large number of these 19 species are highly ornamented gastropods. This indicates that the Briones is probably a part of the San Pablo series. However, considering that there are 29 species, or 41 per cent, found only in the Briones, and only 6 species peculiar to the Briones and the Lower San Pablo group, and because of the stratigraphic evidence mentioned above, the

indication is that the Briones is a separate minor cycle of deposition. This would make the San Pablo series consist of three minor cycles of deposition—Briones, "Lower San Pablo," and "Upper San Pablo."

PHYSICAL AND ECONOMIC GEOGRAPHY OF OREGON

BY WARREN DU PRE SMITH

(Abstract)

The paper, which is not yet completed, though practically all the chapters are in first draft, is the result of several years' work in Oregon on the part of the author and embraces as complete a survey of the existing literature as can be found dealing with the subject. The table of contents appended will give an idea of the subject-matter. A great deal of the data in this paper has never yet appeared in print and some of the material drawn on from the literature has received new interpretation.

Among the chief points emphasized in this research is the influence of physiographic and climatic (particularly those of light and winds) features in Oregon; the part played by geographic location in Oregon's history and development. Still another theme is the matter of relationship of political and physical boundaries. The land problem in Oregon is taken up under such heads as the reserve lands, the logged-off lands, the arid lands, the undrained lands. There is a chapter on the geographic location of cities and some attempt is made to prognosticate, from a study of the geology and geography of the State, the future of Oregon's economic development.

GEOLOGY OF PALESTINE

BY REGINALD W. BROCK

*LATE CENOZOIC MAMMALIAN REMAINS FROM THE MEADOW VALLEY REGION,
SOUTHEASTERN NEVADA*

BY CHESTER STOCK

(Abstract)

J. E. Spurr, in a paper entitled "Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California," has directed attention to the Pliocene continental deposits occupying an extensive territory in the Meadow Valley region of southeastern Nevada. The determination of age of these beds was, however, not based on paleontological evidence.

Two areas are now known in this province of Nevada where well exposed sedimentary deposits have yielded mammalian remains. The northern area comprises Meadow Valley, an intermontane inclosure bounded on the west by the Highland Range, on the east and south by the Mormon Range, and on the north by the Pioche Range. Near the village of Panaca, Lincoln County, Nevada, the deposits in which mammalian remains occur consist of red-brown and green colored sands and clays. Cross-bedded sands and gravels as well as tuffaceous materials are also present. The beds show the effect of slight folding. Several series of terraces are developed in these sediments. The mam-

malian fauna consists of a camel, possibly *Pliauchenia*, an advanced type of horse related either to *Pliohippus* or to *Equus*, and a rhinoceros. The fauna suggests that the deposits are of Pliocene age. The mammal-bearing sediments of Meadow Valley may be known as the Panaca beds.

Approximately 80 miles south of Panaca, in Meadow Valley, a second series of mammal-bearing deposits is exposed, in Muddy Valley. These beds are mapped by Spurr as Pliocene. Between the villages of Overton and Logan, Lincoln County, Nevada, and on the southwest side of the Muddy River, the deposits consist of well indurated sands and clays, red or light brown in color. They rest unconformably on a series of beds that are presumably of early Tertiary age. The mammal-bearing sediments of Muddy Valley are also terraced. In the well indurated sands and clays a small collection of mammalian remains was secured. Camels and apparently a horse are the only members of this Tertiary fauna. The forms differ from those found in the Panaca beds. The faunal difference suggests that the northern and southern deposits are not of same age. Possibly the mammal-bearing beds of Muddy Valley, which may be designated the Muddy Creek beds, are earlier in age than the Panaca deposits.

CORRELATION OF THE EMPIRE FORMATION, OREGON

BY HENRY V. HOWE

(Abstract)

1. The Empire fauna is Lower Pliocene in age because the Wildcat, Merced, Purissima, and other Lower Pliocene formations of California, whose position in the Tertiary is already recognized, contain many highly ornamented species of mollusca common to the Empire. Pliocene age of the Empire is indicated also by the presence of the genus *Dendraster*.

2. The Coos conglomerate, lying with irregular contact on the Empire beds, is also of Pliocene age.

OBSERVATIONS ON THE SKELETON OF THE CAVE BEAR, ARCTOTHERIUM

BY JOHN C. MERRIAM

CORRELATION AND PALEOGEOGRAPHY OF THE MARINE TERTIARY DEPOSITS OF THE WEST COAST

BY BRUCE L. CLARK

(Abstract)

The introduction to the paper considers the methods and principles of correlation applied to the problem of marine beds of the Pacific coast. The main part of the paper will discuss a proposed tentative correlation table, with accompanying paleogeographic maps.

**GEOLOGIC OCCURRENCE OF THE HARDGRAVE JURASSIC FAUNA OF BURIA
OREGON.**

BY E. L. PACKARD AND E. N. NELSON

(Abstract)

The lower Jurassic of eastern Oregon has heretofore been known only through the meager fauna early obtained by Thomas Condon from Silvies Canyon, Harney County. The fauna was recently found to occur in a series of sedimentary and associated intrusive rocks outcropping only within the canyon of Silvies River. This series includes red impure limestone, light-colored limestone, fine-grained shale, arenaceous shale, arkosic sandstone, and basic intrusives. The fauna of nearly fifty species is mainly confined to the red impure limestone, though occasional specimens were found in the shale members. The beds apparently are dipping steeply southward and are unconformably overlain by supposed Columbia River lava.

AN ADDITION TO THE MARINE MAMMALIAN FAUNA OF NEWPORT, OREGON

BY E. L. PACKARD

(Abstract)

The Newport region of Lincoln County, Oregon, has already yielded teeth of *Desmostylus* sp., obtained by Condon from the beach of Yaquina Bay; a skull of *Desmatophoca oregonensis* Condon, and recently discovered cetacean remains. Stratigraphic studies make it apparent that these mammalian specimens were all derived from the Monterey Miocene, which is well exposed at Newport and which has yielded a characteristic invertebrate fauna. A nearly complete cetacean skull, lacking the distal ends of the mandibles and portions of the squamosals; a number of vertebrae, several ribs, and various elements of the pectoral girdle, including fairly well preserved scapulae, were found in the ocean beach west of Newport. Preliminary studies indicate that this specimen should be referred to the Balænidæ, but its generic position is as yet undetermined.

TRIGONINÆ OF THE PACIFIC COAST OF NORTH AMERICA

BY E. L. PACKARD

(Abstract)

The oldest Trigonina fauna of the west coast of North America occurs in the Hardgrave Lower Jurassic of Taylorsville, California. The group Clavellatæ and Costatæ are represented by the two species, both of which are related to southern Asiatic forms and one of which may well be taken as ancestral to a Middle Jurassic species. The third group of the genus, the Undulatæ, is represented in the Middle Jurassic of the Cordilleran region, while the Glabræ, Scabræ, and Scaphoidea are known from the Mormon Jurassic of California. The genus is not represented in the Knoxville Cretaceous. The Horsetown and Chico faunas include 12 species and one variety, seven of which are new. One of these is considered a new variety of a Japanese species.

PECCARY FROM RANCHO LA BREA

BY JOHN C. MERRIAM AND CHESTER STOCK

(Abstract)

Peccary remains from Rancho La Brea indicate the presence of the genus *Platygonus*. The species is closely related to *P. leptorhinus* and *P. compressus*. It may, however, be specifically or subspecifically distinct from known North American forms of the Pleistocene.

Meeting adjourned.

ELECTION OF OFFICERS

Results of an election of officers held during October, 1920, indicate that the following selections were made:

President, Dr. E. L. PACKARD, University of Oregon, Eugene, Oregon.

Vice-President, Prof. B. L. CLARK, University of California, Berkeley, California.

Secretary, Dr. CHESTER STOCK, University of California, Berkeley, California.

CONSTITUTION AND BY-LAWS OF THE PALEONTOLOGICAL SOCIETY

CONSTITUTION

ARTICLE I

NAME

This Society shall be known as THE PALEONTOLOGICAL SOCIETY. It is affiliated with and forms a section of the Geological Society of America. The two societies shall, as a rule, meet together.

ARTICLE II

OBJECT

The object of this Society is the promotion of the Science of Paleontology.

ARTICLE III

MEMBERSHIP

The Society shall be composed of Fellows, Members, Correspondents, and Patrons.

1. Fellows shall be persons who have published results of paleontological research, and who upon nomination by the Council have been duly elected to fellowship by the Geological Society of America.

2. Members shall be persons not Fellows who are engaged or interested in paleontological work.

3. Correspondents shall be persons distinguished for their attainments in Paleontology and not resident in North America.

4. Patrons shall be persons who have bestowed important favors upon the Society. Election to patronship carries with it the rights and privileges of Members.

5. Fellows, Members, and Patrons are entitled to vote, but only Fellows are eligible to office in the Society.

ARTICLE IV

OFFICERS

1. The Officers of the Society are a President, three Vice-Presidents, a Secretary, a Treasurer, and an Editor.

These officers constitute an Executive Committee to be called the Council.

2. The President shall discharge the usual duties of a presiding officer at all meetings of the Society and of the Council. He shall take cognizance of the acts of the Society and of its officers, and cause the provisions of the Constitution and By-Laws to be faithfully carried into effect. The President shall also represent THE PALEONTOLOGICAL SOCIETY in the Council of the Geological Society of America.

3. The Vice-Presidents, in the order of their precedence, shall assume the duties of President in case of the absence or disability of the latter.

The three Vice-Presidents represent respectively the three chief branches of paleontology, and it shall be the duty of each to look after the interests and preside at the meetings of the section which he represents.

4. The Secretary shall keep the records of the proceedings of the Society, and a complete list of the Fellows, Members, Correspondents, and Patrons, with the dates of their election to and separation from the Society. He shall also be the Secretary of the Council.

The Secretary shall cooperate with the President in attention to the ordinary affairs of the Society. He shall attend to the preparation, printing, and mailing of circulars, blanks, and notifications of elections and meetings. He shall superintend other printing ordered by the Society or by the President, and shall have charge of its distribution, under the direction of the Council.

The Secretary, unless other provision be made, shall act as Librarian, and as Custodian of the property of the Society, except as provided for in Article IV, section 6.

5. The Treasurer shall have the custody of all funds of the Society except the fees of Fellows. He shall keep account of receipts and disbursements in detail, and this shall be audited as hereinafter provided.

6. The Editor shall supervise all matters connected with the publication of the transactions of the Society under the direction of the Council. He shall also be the keeper of all publications sent to the Society.

7. The Council is clothed with executive authority and with the legislative powers of the Society in the intervals between its meetings; but no extraordinary act of the Council shall remain in force beyond the next following stated meeting without ratification by the Society. The Council shall have control of the publications of the Society, under provisions of the By-Laws and of resolutions from time to time adopted. They shall receive nominations for Fellows, Members, Correspondents, and Patrons, and, on approval by them, shall submit such nomination to the Society for action. They shall have power to fill vacancies *ad interim* in any of the offices of the Society not otherwise provided for.

8. *Terms of Office.*—The President and Vice-Presidents shall be elected annually. The President shall not be eligible for re-election until after an interval of three years from retirement from office. A Vice-President is eligible for re-election not more than once within such interval.

The Secretary, Treasurer, and Editor shall be eligible to re-election without limitation.

ARTICLE V

VOTING AND ELECTIONS

1. All elections shall be by ballot. To elect a Fellow, Member, Correspondent, or Patron, or impose any special tax, shall require the assent of nine-tenths of all persons voting.

2. Voting by letter may be allowed.

3. *Election to Membership.*—Nominations for all classes of membership must be made by two Fellows according to a form to be provided by the Council.

One of these Fellows must be personally acquainted with the nominee and his qualifications for membership. The Council will submit the nominations received by them, if approved, to a vote of the Society in the manner provided in the By-Laws. The result may be announced at any stated meeting; after which notice shall be sent out to the elect.

4. *Election of Officers.*—Nominations for office shall be made by the Council or otherwise as provided for in the By-Laws. The nominations shall be submitted to a vote of the Society in the same manner as nominations for membership. The results shall be announced at the annual meeting; and the officers thus elected shall enter upon duty at the adjournment of the meeting.

ARTICLE VI

MEETINGS

1. The Society shall hold at least one stated meeting a year in the winter season. The date and place of this meeting shall be fixed by the Council, and announced each year within three months after the adjournment of the preceding winter meeting. The program of such meeting shall be determined by the Council in conjunction with the Council of the Geological Society of America and announced beforehand, in its general features. The details of the daily sessions shall be arranged by the Council of this Society.

2. The winter meeting shall be regarded as the annual meeting.

3. Special meetings of the Society as a whole or of any of its sections as sectional meetings may be called by the Council, and must be called upon the written request of ten Fellows, for a general meeting and of five Fellows for any of its sections.

4. The stated meetings of the Council shall be held coincidently with the stated meeting of the Society. Special meetings may be called by the President at such times as he may deem necessary.

5. *Quorum.*—At meetings of the Society a majority of those registered in attendance shall constitute a quorum. Four shall constitute a quorum of the Council.

ARTICLE VII

PUBLICATIONS

The publications of the Society shall be under the immediate control of the Council.

ARTICLE VIII

AMENDMENTS

1. This Constitution may be amended at any winter meeting by a three-fourths vote of all the Fellows, provided that the proposed amendment shall have been submitted in print to all Fellows at least three months previous to the meeting.

2. By-Laws may be made or amended by a majority vote of the Fellows present and voting at any annual meeting, provided that printed notice of the proposed amendment or by-law shall have been given to all Fellows at least three months before the meeting.

BY-LAWS

CHAPTER I

MEMBERSHIP

1. All Fellows of the Geological Society of America in good standing whose work is primarily in paleontology may, upon application to the Council of this Society, be elected without additional dues as Fellows of The Paleontological Society. Such Fellows, if Life Members of the Geological Society, will have no further dues to pay in The Paleontological Society.

2. No person shall be accepted as a Fellow of The Paleontological Society unless he pay to the Geological Society of America the initiation fee and the dues for the year within three months after notification of his election. The initiation fee of Fellows shall be ten (10) dollars and the annual dues ten (10) dollars, payable on or before the annual meeting in advance; but a single prepayment of one hundred (100) dollars shall be accepted as commutation for life.

The annual dues for Members shall be three (3) dollars. No person shall be accepted as a Member unless he pay the dues for the year within three months after notification of his election. The annual dues are payable to The Paleontological Society on or before the annual meeting.

3. An arrearage in payment of annual dues shall deprive a Fellow or Member of the privilege of taking part in the management of the Society and of receiving the publications of the Society. An arrearage continuing over two (2) years shall be construed as notification of withdrawal.

4. Any person eligible under Article III of the Constitution may be elected Patron upon the payment of one thousand (1,000) dollars to the Society.

CHAPTER II

OFFICIALS

1. The President shall countersign, if he approves, all duly authorized accounts and orders drawn on the Treasurer for the disbursement of money.

2. The Secretary, until otherwise ordered by the Society, shall perform the duties of Editor, Librarian, and Custodian of the property of the Society.

3. The Society may elect an Assistant Secretary.

4. The Treasurer shall give bonds, with two good sureties approved by the Council, in the sum of one thousand dollars, for the faithful and honest performance of his duties and the safe-keeping of the funds of the Society. He may deposit the funds in bank at his discretion, but shall not invest them without authority of the Council. His accounts shall be balanced as on the thirtieth day of November of each year.

5. The minutes of the proceedings of the Council shall be subject to call by the Society.

6. The Council may transact its business by correspondence during the intervals between its stated meetings; but affirmative action by a majority of the Council shall be necessary in order to make action by correspondence valid.

CHAPTER III

ELECTION OF MEMBERS

1. Nominations for all classes of membership may be proposed at any time on blanks to be supplied by the Secretary.

2. The form for nomination shall be as follows:

In accordance with his desire, we respectfully nominate for Fellow, Member, Correspondent, or Patron of The Paleontological Society:

Full name; degrees; address; occupation; branch of Paleontology now engaged in; work already done and publications made.

(Signed by at least two Fellows.)

The form when filled is to be transmitted to the Secretary.

3. The Secretary will bring all nominations before the Council, at the winter meeting of the Society. The Council will signify its approval or disapproval of each, and forward to the Council of the Geological Society of America all approved nominations to Fellowship.

4. At least a month before the stated winter meeting of the Society the Secretary shall mail a printed list of all approved nominees for membership to each Fellow and Member, accompanied by such information as may be necessary for intelligent voting, but an informal list of the candidates shall be sent to each Fellow and Member at least two weeks prior to distribution of the ballots.

5. The Fellows and Members receiving the list will signify their approval or disapproval of each nominee, and return the list to the Secretary.

6. At the next stated meeting of the Council the Secretary shall present the lists and the Council will canvass the returns.

7. The Council, by unanimous vote of the members in attendance, may still exercise the power of rejection of any nominee whom new information shows to be unsuitable for membership.

8. At the next stated meeting of the Society the Council shall declare the results.

CHAPTER IV

ELECTION OF OFFICERS

1. The Council shall prepare a list of nominations for the several offices, which list will constitute the regular ticket. This ticket must be approved by a majority of the entire Council. The nominee for President shall not be a member of the Council.

2. The list shall be mailed to the Fellows and Members, for their information, at least nine months before the annual meeting. Any five Fellows may forward to the Secretary other nominations for any or all offices. All such nominations reaching the Secretary at least 40 days before the annual meeting shall be printed, together with the names of the nominators, as special tickets. The regular and special tickets shall then be mailed to the Fellows and Members at least 25 days before the annual meeting.

3. The Fellows and Members shall send their ballots to the Secretary in double envelopes, the outer envelope bearing the voter's name. At the winter

meeting of the Council, the Secretary shall bring the returns of ballots before the Council for canvass, and during the winter meeting of the Society the Council shall declare the result.

4. In case a majority of all the ballots shall not have been cast for any candidate for any office, the Society shall by ballot at such winter meeting proceed to make an election for such office from the two candidates having the highest number of votes.

CHAPTER V

FINANCIAL METHODS

1. No pecuniary obligation shall be contracted without express sanction of the Society or the Council. But it is to be understood that all ordinary, incidental, and running expenses have the permanent sanction of the Society, without special action.

2. The creditor of the Society must present to the Treasurer a fully itemized bill, certified by the official ordering it, and approved by the President. The Treasurer shall then pay the amount out of any funds not otherwise appropriated, and the receipted bill shall be held as his voucher.

3. At each annual meeting, the President shall call upon the Society to choose two Fellows or Members, not members of the Council, to whom shall be referred the books of the Treasurer, duly posted and balanced to the close of November thirtieth, as specified in the By-Laws, Chapter II, section 4. The Auditors shall examine the accounts and vouchers of the Treasurer, and any member or members of the Council may be present during the examination. The report of the Auditors shall be rendered to the Society before the adjournment of the meeting, and the Society shall take appropriate action.

CHAPTER VI

PUBLICATIONS

1. The publications are in charge of the Council and under its control.

2. One copy of each publication shall be sent to each Fellow, Member, Correspondent, and Patron.

CHAPTER VII

THE PUBLICATION FUND

The Publication Fund shall consist of donations made in aid of publication.

CHAPTER VIII

ORDER OF BUSINESS

1. The Order of Business at winter meetings shall be as follows:

- (1) Call to order by the presiding officer.
- (2) Introductory ceremonies.
- (3) Report of the Council (including report of the officers).
- (4) Appointment of the Auditing Committee.

- (5) Declaration of the vote for officers, and election by the meeting in case of failure to elect by the Society through transmitted ballots.
 - (6) Declaration of the vote for Fellows.
 - (7) Declaration of the vote for Members.
-

The Geological Society of America

Amherst, Massachusetts

28-30 December, 1921

THE BRYOZOA, OR MOSS ANIMALS

BY

R. S. BASSLER

United States National Museum

FROM THE SMITHSONIAN REPORT FOR 1920, PAGES 339-380
(WITH 4 PLATES)



(PUBLICATION 2633)

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THE BRYOZOA, OR MOSS ANIMALS.

By R. S. BASSLER,
United States National Museum.

[With 4 plates.]

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INTRODUCTION.

To the layman the paradoxical term "moss animals" has little significance, and even to the scientific student this, or its Greek equivalent, "Bryozoa," is often no more than a name. Yet these microscopic animals, growing often into mosslike colonies, are extremely abundant in the present-day seas at all latitudes, and their fossil remains are equally common and widespread in almost all the sedimentary rocks since early geologic times. Notwithstanding this great development in both the past and the present, the study of the bryozoa has always been limited to a comparatively few specialists who have been unable to overcome the popular belief that this group of animals presents too difficult a problem for any but the expert willing to spend a lifetime of research upon them. This belief has been strengthened by the fact that practically all of the published works upon the bryozoa are of a highly technical nature and usually deal with some special subject. In none of them is there a review in relatively simple language of the class as a whole. The present article has been prepared in an endeavor to remedy this condition. Descriptions and illustrations of typical examples of the various types of bryozoa, both fossil and recent, the methods employed in studying them, and the interest and value of this study from various stand-points are presented in the hope that the class will in future receive the attention that it deserves.

The bryozoa are perhaps best known to-day from the paperlike fronds called "sea mats" and the mosslike structures tossed upon our seacoasts. These are not plants as was long supposed but are animal colonies consisting of a great number of small cells opening side by side.

Before their true nature was learned these organisms were placed in a halfway group termed "zoophytes," partly animal and partly plant. The coral-like appearance of the calcareous bryozoa gave origin to another term "corallines." When it was discovered, however, that each individual cell of the composite colony contained an animal with a complete alimentary canal totally unlike the corals or any other group with which they had been compared, the name "Bryozoa" was definitely introduced for them as a new group of animals by C. G. Ehrenberg in Germany in 1831. Another term, "Polyzoa," applied by J. B. Thompson in Ireland in 1830, was not so precisely defined, and a long controversy arose concerning the two rival terms. This has been settled by a curious division of opinion, namely, the term "Polyzoa" is preferred by most English naturalists, but all of the continental and American authors employ the designation "Bryozoa."

GENERAL CHARACTERS.

The bryozoa are small, composite, usually marine animals arising from a free-swimming larva which becomes attached to some foreign object and then develops into the primary individual or *ancestrula*. By repeated budding from the *ancestrula*, colonies of various shapes and sometimes considerable size arise. Each individual animal or zooid is composed of a double-walled membranaceous or calcareous sac, the *zoecium*, within which is the visceral mass, the *polypide*, consisting of a freely suspended alimentary canal U-shaped so that the mouth and anus open close to each other. The mouth is surrounded by the *lophophore*, bearing a crown of hollow, slender, ciliated tentacles arranged in a circle or crescent by which microscopic organisms such as diatoms are gathered for food. Both sexes are usually combined in the same zooid. It is a curious fact that the same *zoecium* may be inhabited at different times by different *polypides*.

The colony which the individual zooids form is known technically as the *zoarium*; it presents a great variety of form and structure, although the form is quite constant in individual species. Very frequently the zoaria grow over shells, stones, or other bodies, forming delicate incrustations of exquisite patterns. By the superposition of many such incrustations, hemispherical, globular, nodular, or irregular masses, often of considerable size, may result. Again, the zoaria may arise in fronds or branching stems, and at other times

they form open-meshed lacework of the most regular and beautiful patterns. Most bryozoa are attached either basally or by the greater part of their surface to extraneous objects or are moored to the bottom by rootlike appendages. In many forms the zoarium is regularly jointed to give greater mobility.

The individual zooids of the zoarium conform to a simple and definite type of structure throughout the class. The soft parts of the animal consist of an alimentary canal with three distinct regions discernible—esophagus, stomach, and intestine. The alimentary canal is inclosed in a sac and bent upon itself so that the two extremities are close to each other. The mouth, or oral opening, is either entirely or partially surrounded by a row of slender, hollow, ciliated tentacles which serve for respiration and for sweeping food toward the mouth. The two large divisions under which the bryozoa are classed (Entoprocta and Ectoprocta) are based upon the position of the anal opening. In most cases the anal opening is situated without the row of tentacles (Ectoprocta); rarely it is placed within this row (Entoprocta). A heart and vascular system are wanting, but there are numerous leucocytes floating in the general cavity. A nervous ganglion is present between the mouth and anus and sends delicate nerve filaments to the tentacles and esophagus. The upper part of the sac is generally flexible and can be invaginated through the action of numerous longitudinal and transverse muscles which traverse the fluid-filled visceral cavity.

The reproductive organs are developed in various parts of the body cavity, although the spermatozoa occur usually in the lower and the ova in the upper part. The ova may be developed in a special receptacle, in an inflation of the surface, or in a modified zooecium. The general term oocium or ovicell is applied to all of these structures.

The above general description of the anatomy of the bryozoan applies, with certain exceptions, to all divisions of the class, and more modification in structure is to be observed in the protective covering or home of the animal, the zooecium, than in the animal itself, the polypide. The accompanying diagram of the anatomy of a single zooecium (text fig. 1), with its polypide retracted, will illustrate this general structure. The mouth leads into the ciliated pharynx, and this into the esophagus, followed by the stomach, which in turn passes into the intestine, and this through the rectum, communicates with the exterior by the anus. When retracted the tentacles lie in a cavity, the tentacle sheath, which opens to the exterior by the orifice.

Many bryozoans exhibit, attached to the zooecium, organs resembling a bird's head, termed "avicularia," and other bristlelike appendages named "vibracula." The jaws of the avicularia open

and close with a snapping motion, which has given rise to the probably erroneous idea that they are organs of defense. These two organs are mentioned in more detail in the consideration of the cheilostomatous bryozoa. Both the avicularia and vibracula are incapable of preservation in the fossil state, but their former presence is indicated by the porelike excavations in which they lodged.

The extended polypide is withdrawn into the zooecium by the contraction of retractor muscles attached to the tentacular crown. In the bryozoa with flexible zooecia the contraction of the body walls by parietal muscles produces protrusion of the polypide, but

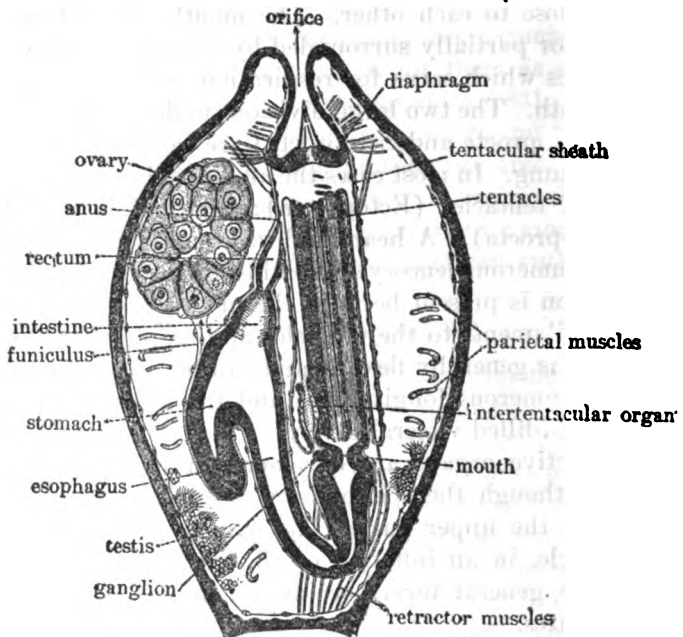


FIG. 1.—Anatomy of the polypide. Diagram showing the anatomy of a single zooecium of *Alcyonidium albidum* Alder, highly magnified, with its polypide retracted. (After Prouho.)

in the rigid calcareous zoaria the means for protrusion are more complicated as explained under the Cheilostomata.

The zooecium, the protective covering of the polypide, varies so much in structure that its description is reserved for the discussion of each order.

CLASSIFICATION.

The first serious attempt at a classification was made by D'Orbigny,¹ whose wide acquaintance with recent and fossil bryozoa has perhaps been equaled by no subsequent writer. But the system he devised was so largely artificial and burdened with so perplexing a

¹ 1850-1852. D'Orbigny. *Paléontologie française, Terrain Crétacé*, Vol. V.

nomenclature that it failed to gain acceptance. The labors of Nitsche, Allman, and Busk have fixed the principal groups. To Nitsche³ is due the division into the two groups Ectoprocta and Entoprocta, the latter containing only a few, singular genera such as *Pedicellina* and *Loxosoma*. Allman⁴ formed the orders Phylactolaemata and Gymnolaemata, the latter including most of the bryozoa and all forms capable of preservation as fossils. Busk's suborders Cheilostomata, Cyclostomata, and Ctenostomata⁴ are now generally accepted as orders. To these Ulrich, in 1882,⁵ added the Trepotomata, to include, besides uncontested bryozoa, a number of forms which had been generally regarded as corals; and Vine, in 1883,⁶ added the Cryptostomata, which like the Trepotomata is known only from fossil forms.

The bryozoa and the brachiopoda are considered as constituting the phylum Molluscoidea, although some authors believe there is no relationship between them and regard the bryozoa as representing a distinct phylum. The two large subdivisions of the bryozoa, Ectoprocta and Entoprocta, based upon the position of the anus with reference to the tentacles, have been mentioned before. These subclasses differ widely from each other in many respects and here again some authors believe they are not even distantly related. However, the great majority of these animals belong to the Ectoprocta and under this to the superorder Gymnolaemata. Five orders of Gymnolaemata are known, of which the Cheilostomata is perhaps the largest in number of species. The relations of these various classificatory terms are expressed in the following table:

Phylum MOLLUSCOIDEA.

Class BRYOZOA.

Subclass ENTOPROCTA.

Row of tentacles circular, inclosing both the mouth and anal orifice.

Subclass ECTOPROCTA.

The tentacles surround the mouth only.

Superorder PHYLAETOLAEMATA.

Fresh-water Ectoprocta with the tentacles arranged in horseshoe shape and the mouth protected by an overhanging lip.

Superorder GYMNOLAEMATA.

Almost exclusively marine Ectoprocta with a circular row of tentacles surrounding the mouth, which is at their center.

³1869. Nitsche. Beitschrift für wissenschaftliche Zoologie, Vol. XX.

⁴1856. Allman. Monograph of the Freshwater Polyzoa, p. 10.

⁴1852. Busk. British Museum Catalogue of Marine Polyzoa.

⁵1882. Ulrich. Journal Cincinnati Society Natural History, Vol. V, p. 151.

⁶1883. Vine. Report British Association Advancement Science, p. 196.

Order 1. CTENOSTOMATA.

Zooecia gelatinous or chitinous with toothlike processes resembling a comb closing the aperture when the tentacles are retracted. Range, Paleozoic to Recent.

Order 2. CYCLOSTOMATA.

Zooecia calcareous and tubular with a circular aperture. Range, Paleozoic to Recent.

Order 3. TREPOSTOMATA.

Zooecia calcareous and superposed upon each other so as to form long tubes intersected by straight or curved partitions, and showing an axial, immature zone and a peripheral, mature zone. Monticules or maculae of larger or smaller cells distributed on the surface at regular intervals. Range, Paleozoic only.

Order 4. CRYPTOSTOMATA.

Gymnolaemata differing from the Trepostomata in that the primitive part of the tube is usually much shorter and the passage to the mature region is more abrupt. Triparietal gemmation. Probably the Paleozoic representatives of the Cheliosomata.

Order 5. CHEILOSTOMATA.

Zooecia calcareous or chitinous with the aperture closed when the polypide is retracted, by a chitinous lip or operculum. Range, Mesozoic to Recent.

COLLECTION AND PREPARATION FOR STUDY.

In view of their abundance in the sedimentary rocks and in the recent seas, collecting specimens of bryozoa is a simple matter although certain features of it should be mentioned. With regard to the fossil forms, bryozoa are practically wanting in most sandstone strata, but beginning with the Ordovician there is scarcely a limestone formation, especially if it has shale alternations, in which they are not abundant. Generally the specimens are calcareous, and in this condition are easily sectioned for study under the microscope by the method mentioned later. Sometimes, however, they are found silicified and the internal structure is, to a certain extent, obliterated so that they can then rarely be successfully sectioned for study. Such specimens, however, frequently preserve the surface characters with great fidelity. In certain strata their substance has been dissolved away leaving a perfect mold in the matrix. A gutta-percha impression of this mold will often give a very satisfactory idea of the exterior of the original fossil.

The best specimens are usually obtained from the shales between or just above or below limestone layers. The smaller forms may be obtained free by carefully washing the shales and picking them out from the débris. Some kinds of shales or clay will wash away better if first allowed to become thoroughly dry. Others do better after thorough soaking in water.

Often the surface characters are obscured by the clayey matrix. This may be removed by the use of caustic potash (KOH in stick

form). The deliquescence of small pieces of this substance, which needs to be handled gingerly with unprotected hands, laid upon the fossil loosens the clay, which is then easily brushed off. Some workers accomplish the same result by placing their specimens in a saturated solution of Glauber's salts, which, in crystallizing, also loosens the clay. To prevent continued action of the small amount of caustic potash still remaining the specimen must be carefully neutralized by washing in water containing very dilute hydrochloric acid.

The Paleozoic species usually belong to the so-called stony bryozoa (pl. 1) in which the zoarial fragments are large enough to be readily visible to the collector. In weathered outcrops these fossils occur as twiglike fragments or lace-like fronds, often so numerous that they can be gathered in large quantities. The solid limestone, such as, for example, the well-known Tennessee marble, is often crowded with branching and rounded fragments of stony bryozoa, which can not be broken out of the rock without destroying the form of the zoarium. Fortunately these can be identified by thin sections just as readily as the free specimens.

Mesozoic and Cenozoic bryozoa occur in unconsolidated sediments more frequently than in the Paleozoic, so that free specimens are very easily obtained. However, although these bryozoans often occur literally by the millions in a stratum, they are usually so inconspicuous as to be unnoticed by the average collector. When these fossils are present, a careful examination of a weathered outcrop will almost invariably reveal a few minute twiglike stems or porous, flattened fragments projecting from the surface. Further search along the outcrop, especially along a seam in the rock, is very liable to result in the discovery of many such fragments (pl. 2).

As most of the post-Paleozoic bryozoa occur in soft limestone or marls, the collection of the material for study consists simply in scooping up a large amount of the loose rock containing these fragmentary remains. If the specimens are found in a hard, indurated rock it is usually only a matter of search to find a spot where the matrix has decomposed, leaving the soil filled with free specimens. In any case it is not advisable to pick up the specimens one by one, not only on account of loss of time but also of breakage. On arriving at the laboratory the clay or other rock holding the bryozoans should be allowed to soak in water for some hours. The material may then be agitated and the muddy water poured away. Continuing this process until the agitated water no longer becomes muddy, the residual mass is set aside to dry. The débris when dry is then ready for assorting, although passing it through several sieves of different mesh greatly facilitates the separation of the contained fossils.

When bryozoa are quite rare in any exposure it is well to do most of the sieving in the field, if possible. For example, the interesting

lowest Eocene fauna secured at Upper Marlboro, Maryland, was collected only after several days' active work of sieving the sand; and a small pill box was sufficient to hold the entire results.

In case these fossils can not be found in soft rock it is often still possible to obtain good specimens for study. A comparatively hard fossiliferous rock, when crushed in a sack with a wooden mallet, will often afford fairly well-preserved fossils after the débris has been washed and sieved as mentioned above. In such a case the bryozoans, although likely to be broken into smaller fragments than usual, are generally well enough preserved for accurate determination. If the rock is calcareous and too hard to yield to such treatment, thin sections may be employed to determine the bryozoa.

The separation into species of the fragmentary specimens resulting from the washings can be made with an ordinary hand lens, magnifying 8 or 10 diameters. The identification of these species can also be made under such a lens providing the species have already been well described and illustrated. In the identification and discovery of the characters of new species, however, a higher magnification is necessary.

Bryozoa in the recent seas are collected in quantity by dredging (pl. 2), although a thorough search of seaweeds and shells cast upon the beach or of piling and other structures exposed at low tide will reveal them in considerable numbers. A prolific source of bryozoa for the student is the common oyster and clam of Eastern markets. Many of the specimens secured in the above ways are dead, that is, they contain no living polypides. The study of such bryozoa follows the various methods indicated for the fossil forms. Specimens retaining the polypide may be preserved in alcohol or formaldehyde for an indefinite time before the structure of the animal itself is lost. After decalcifying and embedding in paraffin, thin sections of such specimens may be cut with the microtome as usual for tissues. If the removal of the animal matter is desired in order to study the zooecia unobscured, boiling in Javelle water as described below is necessary.

METHODS OF STUDY.

The relationship between the polypide or living animal and the zooecium or home which it secretes for itself, is such that the study of recent bryozoa embraces two distinct processes, first that dealing with the anatomy of the polypide itself interpreted by the usual histological methods, and second, the determination of the structures belonging to the zooecia. The first is a subject upon which much remains to be done and the attention of biologists is directed to it as a favorable field for research. The second will be discussed in some detail here because the classification of the bryozoa and the identifica-

tion of the fossil forms particularly, is based upon the zooecial structure.

On account of the compound calcareous colonies which many of the bryozoa build, thin sections are a necessity in the study of some of the orders, particularly the Trepotomata and Cryptostomata or fossil stony bryozoa. Again the zoaria of many of the Cyclostomata are so similar to those of the Trepotomata that thin sections are here again required, while even in the Cheilostomata they are frequently needed. The preparation of thin sections is described in a subsequent paragraph.

In the Cheilostomata the form of the chitinous appendages such as the operculum and the mandible of the avicularium is an essential feature, and hence the preparation of these structures for examination under the microscope as well as other preparations as described on p. 371, are necessary in detailed study.

Javelle water.—The various zooecial structures in the recent bryozoa are sometimes obscured by the ectocyst, the chitinous membrane covering the zoarium and by remains of the animal tissue. These are removed by boiling in Javelle water,⁷ whereupon the specimen assumes the aspect of the fossil forms in which naturally all of the chitinous and fleshy parts of the organism have disappeared.

Ammonium-chloride process.—The zoaria of many recent bryozoa are so semitransparent or glasslike that the various zooecial structures can be observed only with difficulty. However, they may be brought out in great perfection and clearness by whitening the surface with ammonium chloride. A simple apparatus for this purpose is illustrated in figure 2. By blowing through the mouthpiece, M, the fumes of hydrochloric acid (HCl) and ammonia (NH₄OH) will unite at the outlets of the tubes, O, and form a white sublimate of ammonium chloride upon any object held at this point. This sublimate can be deposited upon the object in such a uniform, thin film, varying in color according to its thickness, from a light blue to an ivory white, that all the details of structure are reproduced perfectly and can be viewed under the microscope without exhibiting any crystalline structure of the ammonium chloride. By this process the minute sculpturing or structures scarcely visible on the corneous or transparent calcareous colony are brought out in clear relief. While this whitening process is a great aid in the preliminary study it is almost indispensable in the illustration of recent bryozoa by photography. Fossil bryozoa also lend themselves admirably to this process of study and illustration. It may be remarked that the am-

⁷ Javelle water can usually be obtained from any druggist, but it is easily prepared by dissolving 1 pound of washing soda in 1 quart of cold water and adding to this one-quarter pound of ordinary bleaching powder (calcium hypochlorite). After filtering, the solution should be kept in a tightly closed bottle.

monium-chloride deposit can be removed by simply blowing the breath upon the object so coated. The hydrochloric acid and ammonia used should be of great strength to secure the best results. Small quantities only should be employed so that the bottles can be emptied and dried frequently, as the reagents not only absorb moisture but lose their strength in a day or two of use.

Thin sections.—The preparation of satisfactory sections is not difficult but some experience and care are required to produce uniformly good results. Without a machine for cutting rock sections the following method gives excellent results. The materials required are, first, a piece of sandstone 8 or 10 inches wide, several inches thick,

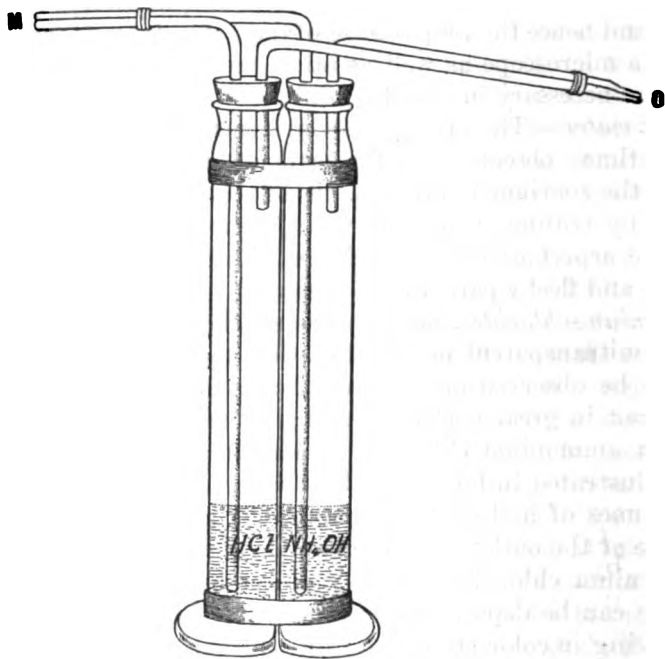


FIG. 2.—Apparatus for preparation of ammonium chloride sublimate.

and 18 or 20 inches long; second, a water hone an inch thick and 4 or 5 inches long; and third, a block of wood 2 inches wide, 4 or 5 inches long, and an inch thick. In place of the sandstone a carborundum slab about an inch thick, 8 inches wide and 18 inches long, to be obtained from the Carborundum Co., at Niagara Falls, is very durable and more efficient. The wooden block should have its upper edges rounded to fit the hand, while on the lower side an excavation should be made of a size to fit the ordinary glass slip. A carborundum hone of considerable fineness is also quite useful.

The procedure for sectioning specimens large enough to be handled without difficulty is as follows: With a pair of wire nippers a frag-

ment is pinched from the specimen and is rubbed upon the sandstone until the surface of which a section is desired is perfectly flat. This surface is then smoothed upon the hone, after which it is cemented upon a glass slip with Canada balsam. The heating of the glass slip to harden the Canada balsam is the most important part of the process, for if the balsam be allowed to boil too long on the heating stage or over a lamp it will be brittle when cold and the fragment will spring off; if too short a time, the section when thin will granulate. After heating and subsequent cooling, the balsam should be tested for hardness, the correct degree being intermediate between brittleness and the point where the finger nail can make an impression upon it. If too soft, the slip must be reheated; but if too hard, it is better to remove the fragment, clean it by smoothing it off on the hone, and then reheating again. When of the proper hardness, the glass slip is then placed in the excavation of the wooden block, which is dipped into water to secure adhesion. Then after rubbing away upon the sandstone or carborundum slab all of the superfluous material until the section is quite thin, the slide is removed from the block and the thinning of the section is completed upon the hone.

In this process the glass slip becomes scratched and unsightly, so for a permanent mount the entire slip should either be ground down to give the ground-glass effect or, better still, the thin section should be transferred to a clean slip and covered in the usual way for permanent preservation. The transfer is accomplished by first cleaning off all old gum around the section with alcohol, then adding a drop of fresh gum, heating, and when the thin section has become loosened sliding it onto a clean glass slip with a sharp-pointed instrument.

Specimens too small to be cut with the wire nippers are sectioned by placing them on a slide in balsam which has been only partially hardened by heating. They may then be rubbed down until the required surface of the section is reached. The balsam is then melted and the specimens are turned over with a sharp-pointed instrument. After cooling, the thin sections are made in the manner described above.

Although this method of sectioning applies particularly to the Trepostomata, it is employed to advantage in species of the other orders where the zoarium is a solid mass composed of numerous tubes. In all cases these sections must be prepared to show the peculiar structural features of the bryozoa, particularly the inner immature zone and the outer peripheral area, where the zooecia are in the mature state and develop accessory features, such as acanthopores, mesopores, diaphragms, etc. To observe these features two sections are always needed, a vertical section parallel with the axis of growth of the tube and a tangential section parallel to the surface and close enough to it to show the structure of the mature zooecia.

Various other preparations necessary in the study of certain groups of bryozoa are described under the discussion of these groups.

In the study of the bryozoa two bibliographies are useful, one by Miss Jelly on the recent species⁸ and the second by Nickles and Bassler,⁹ which, in addition to the citations of all North American fossil species, includes a complete list of the literature up to the date of publication, classified in various ways for easy reference.

TYPES OF BRYOZOA.

The zooeccial structural features and methods of study of the bryozoa differ so decidedly for the various divisions that it is preferable to consider each one separately.

Subclass ENTOPROCTA.

Of the two very unequal major divisions of the bryozoa, the Entoprocta, characterized, as indicated in the name (*endon*=within, *proktos*=anus), by the position of the anal opening within the row of tentacles, is especially interesting in that the comparatively few species classified here probably represent the most primitive expression of the class. In this subclass the tentacles during retraction of the polypide are infolded into a vestibule which can be closed by a sphincter. Definite excretory organs are present as are also reproductive organs which have ducts leading to the vestibule. The different zooids or individuals formed by budding, are further marked by their isolation from each other. In this respect the subclass differs from almost all other bryozoa, as the rule is for adjacent zoecia to be in contact. In *Loxosoma*, a typical entoproctous genus, colonies even are not formed as each zooid leads an independent existence.

As shown in figure 3, these bryozoa grow from a thread-like stolon emitting cylindrical stalks each of which expands into the body of a zooid. The calyxlike zooids are lost from time to time and then the end of the stalk generates another polypide bud which matures into a new calyx. In no case is the body wall calcified so that the Entoprocta is not represented in the fossil state.

Loxosoma and *Pedicellina* represented in figure 3, and *Urnatella* are the best known genera. *Urnatella* is a beautiful form found at present only in fresh water in the United States. In this genus the calyx surmounts a segmented stalk and the stalks arise quite regularly in pairs from a common base. For a more detailed account of the Entoprocta the reader is referred to Ehler's work of 1890.¹⁰

⁸ 1889. Jelly, E. C. Synonymic Catalogue of Recent Marine Bryozoa.

⁹ 1900. Nickles and Bassler. Synopsis of American fossil bryozoa, Bull. 173, U. S. Geol. Surv.

¹⁰ 1890. Ehlers, Zur Kenntniss der Pedicellineen. Abhandlungen der physical. Klasse der Königl. Gesellschaft der Wissenschaften zu Göttingen, XXXVI, pp. 1-200, pls. 1-5.

Subclass ECTOPROCTA.

Almost all of the known bryozoa, both fossil and recent, belong to the Ectoprocta (*ektos*=without, *proktos*=anus), characterized by the position of the anus without the row of tentacles surrounding the mouth. Here again two very unequal divisions have been instituted, the Phylactolaemata with a horseshoe-shaped lophophore, represented by a few species, and the Gymnolaemata, with a circular lophophore, comprising practically all the fossil forms and the great

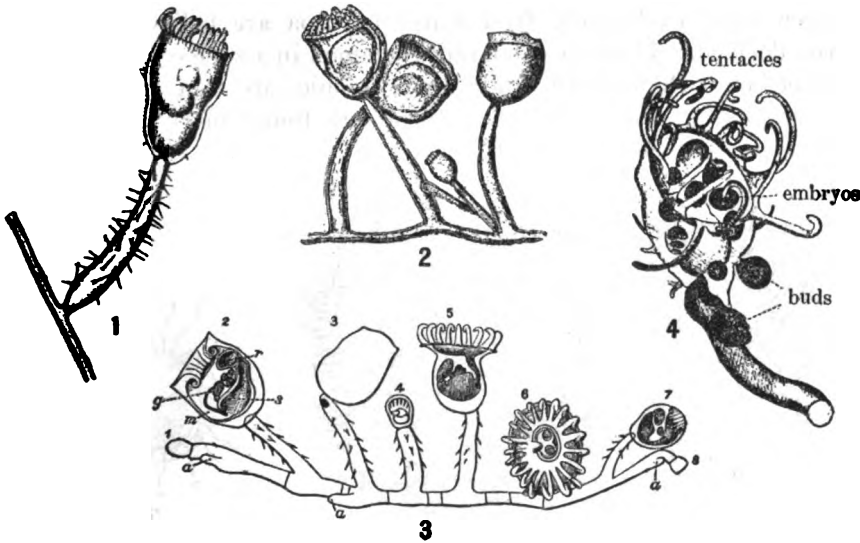


FIG. 3.—Structure of the Entoprocta. 1-3, *Pedicellina cernua* Pallas. Atlantic off England. 1. Polypide borne on a flexuous stolon showing a spinose peduncle, X36. 2. Several polypides in various stages of growth, X20. (After Hincks.) 3. An entire colony, X22, exhibiting three growing ends (*a*); zooids 1 and 8 are quite immature; 7 (tentacles retracted) is still young; 2 is seen in longitudinal section; *g*, generative organ, and below it the ganglion; *m*, mouth; *r*, rectum; *s*, stomach; between *g* and *r* are three embryos in the brood-pouch; the tentacles are retracted; in 5 and 6 the tentacles are expanded; in 6 two embryos are seen within the circle of the tentacles; to the left of them is the rectum, and to the right the mouth; 3 is in the act of losing its calyx, and has already developed the beginning of a new polypide-bud; in 4 the primary calyx has been lost, and the new calyx is clearly marked off from the stalk. 4. *Lososoma oliviferum* Harmer, an entoproctous bryozoan from the East Indies. A female polypide magnified, showing the circle of tentacles with several embryos within them and buds in various stages of development. (After Harmer.)

majority of living species. Unlike the Entoprocta, the reproductive organs are developed in the body cavity and have no ducts leading into the vestibule, while specific excretory organs are absent.

Superorder PHYLACTOLAEMATA.

The bryozoa of this superorder have the tentacles arranged in a horseshoe shape about the mouth, which is protected by an overhanging lip. They are fresh water in their habitat and have special peculiarities which allow them to live under conditions where the

change of temperature and the danger of drying up is ever present. Their special characteristic is the habit of dying down in the winter with the formation of the so-called statoblasts, hard-shelled reproductive bodies consisting of internal buds protected by a chitinous shell capable of resisting unfavorable conditions for a period and then forming new zooids. Sexual reproduction also occurs as in other bryozoa. The Phylactolaemata have a body structure somewhat similar to the Ctenostomata, the first order of the Gymnolaemata, which also show a tendency to live in fresh water, and from which these exclusively fresh-water bryozoa are believed to have been derived. They are often quite common in a zone of water about 2 feet below the surface, where their colonies are found attached to water plants or stones. A few forms are found in running water but most of them occur in still water.

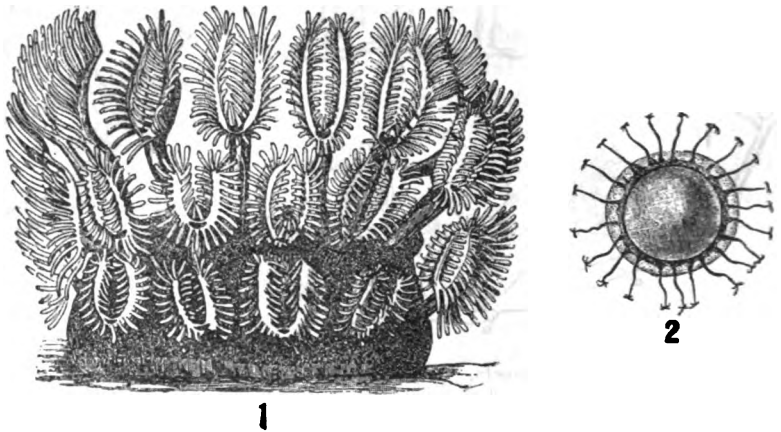


FIG. 4.—*Cristatella mucedo* Cuvier, a fresh-water bryozoan from England, $\times 24$, a typical member of the Phylactolaemata, showing slug-shaped body and the horseshoe-shaped lophophore (1); a statoblast (2) of the same species, $\times 28$.

The zoarium may consist of gelatinous masses of varying size, of aggregations of parallel tubes or of single branching tubes, in all of which cases the body cavities of the zooids are continuous with each other. The body cavity in the Phylactolaemata is thus a continuous space, while in the Gymnolaemata each zooid has its own body wall. As in the Entoprocta, the body wall is uncalcified, and fossil forms are not to be expected. Protrusion of the polypide is effected by the contraction of the muscular body wall compressing the fluid of the body cavity. The tentacles sometimes interlace to form a sort of cage in which infusoria used for food are imprisoned.

Cristatella (text fig. 4), a typical member of the superorder, consists of a slug-shaped gelatinous mass, sometimes eight inches long but only one-half inch wide with a flattened sole on which it has the power of crawling. The protruding polypides form a delicate fringe

along the upper side while around the edge of the mass a zone of budding tissue gives rise to new zooids. *Fredericella*, another typical genus, is a member of the deep-water fauna of the Swiss Lakes. *Plumatella* forms aggregations of parallel tubes. *Lophopus* and *Pectinatella*, like *Cristatella*, show powers of locomotion. These genera have a wide geographical distribution, probably due to their reproduction by statoblasts. They have been recovered from Europe, North and South America, Africa, Australia, and other widely separated areas.

Although the species of Phylactolaemata are comparatively few, they give rise to such interesting phenomena that the literature on these fresh-water bryozoa is quite extensive. The monographs of Allman¹¹ and of Jullien¹² should be consulted for a general review.

Superorder GYMNOLOEMATA.

As mentioned before, this superorder, characterized by the circular row of tentacles surrounding the mouth only, is almost exclusively marine and comprises most of the known recent bryozoa and practically all of the fossil forms. The body cavities are not continuous with one another nor is the body wall muscular as in the Phylactolaemata. In the majority of species, calcareous zooecial walls are deposited and form very interesting objects of study.

ORDER 1. CTENOSTOMATA.

In this order the zooecia, which are frequently isolated, are developed by budding from the internodes of a distinct tubular stolon or stem, thus resembling to this extent the Entoprocta. Again they unite laterally to form sheets, but in both cases the zooecial walls are usually quite soft and uncalcified. The stolon is often threadlike and gives off cylindrical stalks, each of which dilates at its end into the body of the zooid. The zooecial orifice is terminal and is closed during retraction by an operculum of setae, which on account of its resemblance to a comb, gives the name to the order (*ctenos*, comb). All appendicular organs, such as avicularia, ovicells, and vibracula, are wanting. In all the known forms the zooecia are membraneous, and little capable of preservation. In some cases, fortunately, the stolon becomes partially calcified and may thus be preserved fossil, although all traces of the zooecium itself are lost. Then, again, many of the Ctenostomata have the power of excavating a place for themselves in the substance of the host they incrust, so that the size

¹¹ 1856. Allman, G. J. A monograph of the fresh-water Polyzoa, including all the known species, both British and foreign. London, viii + 119 pp. 11 pls.

¹² 1885. Jullien. Monographie des Bryozoaires d'eau douce. Bulletin de la Société Zoologique de France, X, pp. 91-207, 250 figs.

and shape of such excavations serve very well for the identification of many fossil species.

All of the known Paleozoic Ctenostomata have been described by Ulrich and Bassler¹³ in their Revision of the Paleozoic Bryozoa, to which the student is referred for a discussion of these peculiar fossils which had formerly been regarded as trilobite eggs, sponge borings, or foraminifera. Mesozoic and Cenozoic ctenostomatous bryozoa are apparently rare, and little study has been put upon them. In the recent seas, the order is specifically the least represented of

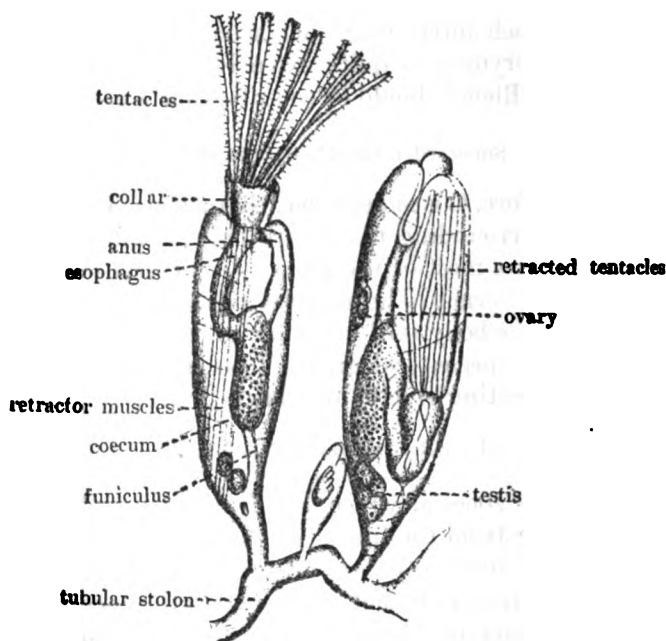


FIG. 5.—Structure of the Ctenostomata. Three polypides of *Ferrelia repens* Farre, rising from a stolon, one with expanded tentacles, another with tentacles retracted, and the third in the young stage, highly magnified. Eastern Atlantic. (After Van Beneden.)

the bryozoa, although some of the species are quite abundant in individuals and widespread. Hincks's¹⁴ memoir of 1880 on British species and Harmer's¹⁵ work on the East Indian forms published in 1915 will give the student a good idea of the recent Ctenostomata. The latter publication includes a good account of the methods of study necessary in this order.

In figure 5 the anatomy of an animal of a recent ctenostomatous bryozoan is illustrated, and its similarity to that in the other order

¹³ 1904. Ulrich and Bassler. Revision of the Paleozoic Bryozoa. Part 1, Ctenostomata. Smithsonian Misc. Coll., vol. 45, pp. 256-294.

¹⁴ 1880. Hincks. British Marine Polyzoa, pp. 488-582.

¹⁵ 1915. Harmer. Polyzoa of the Siboga Expedition, pt. 1, pp. 36-92.

is evident. Figure 6 gives a résumé of the important types of both fossil and recent Ctenostomata. The pinnately arranged stolons of *Rhopalonaria* usually represented by excavations in shells or corals are perhaps the commonest of Paleozoic forms, although the chain-like *Allonema* and the radially arranged bulbs of *Ascodictyon* are occasionally found. The threadlike species are interesting in that the oldest known bryozoan *Heteronema priscum* from the Lowest Ordovician rocks of Esthonia is apparently of this type. In the Mesozoic and Cenozoic eras few Ctenostomata have been found, and all of these show great similarity to the Paleozoic *Rhopalonaria*. However, as only their excavations are usually known, it is probable that the structure of the zooecia was quite different.

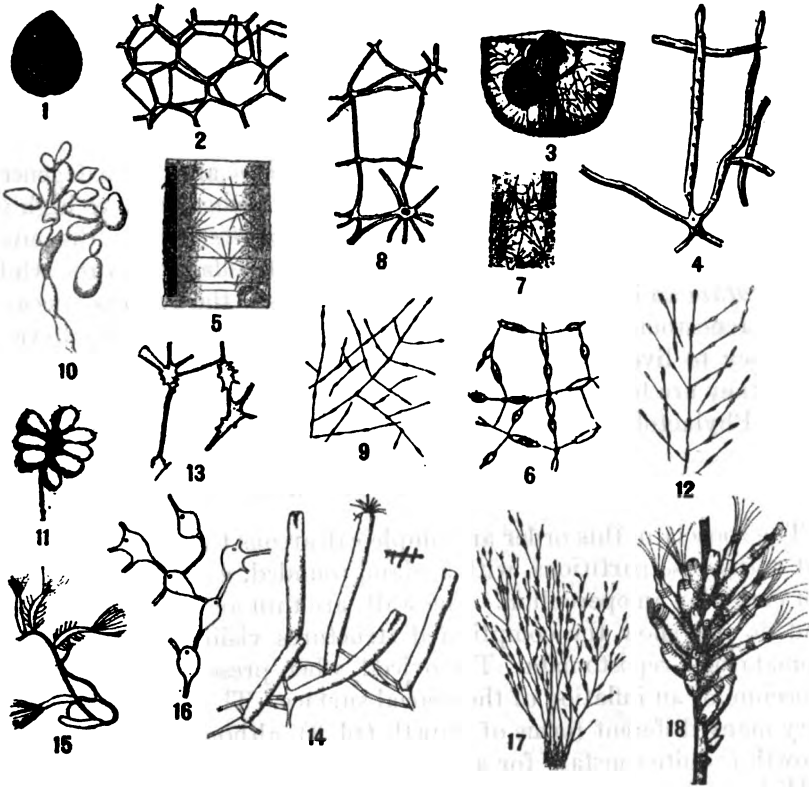


FIG. 6.—Fossil and recent Ctenostomata.

- 1-2. *Heteronema priscum* Bassler. The oldest known bryozoan, a ctenostome from the lowest Ordovician (Ugullite sandstone) of Esthonia; (1) a colony attached to a brachiopod shell, $\times 3$; (2) parts of two colonies, $\times 22$, with one growing over the other.
- 3-4. *Vinella repens* Ulrich, Middle Ordovician shale of Minnesota; (3) two colonies attached to a brachiopod shell, $\frac{1}{2}$ natural size; (4) portion of a zoarium, $\times 12$, showing a nucleus with five divisions of the tubular stolon radiating from it. The pores mark the points where the zooecia were attached.
5. *Vinella radiata* Ulrich. Upper Ordovician, Cincinnati, Ohio. Four colonies attached to a cephalopod shell, two-thirds natural size.

6. *Rhopalonaria venosa* Ulrich. Early Silurian of Southwestern Ohio. Portions of the encrusting colony, $\times 12$.
- 7-8. *Vinella radiiformis conferta* Ulrich from the Silurian (Waldron) shales of Indiana; (7) the encrusting colony, $\times 3$, showing the close development of the nuclei; (8) nuclei and their connecting stolons, $\times 12$.
9. *Rhopalonaria attenuata* Ulrich and Basler, $\times 6$, Silurian (Rochester) shales of New York. This characteristic Silurian species occurs as an excavated mold on shells and other fossils.
10. *Alonema fusiformis* Nicholson and Etheridge, jr. Middle Devonian shale of Michigan. Portion of the encrusting colony, $\times 6$, composed of numerous vesicles.
11. *Ascodictyon stellatum* Nicholson and Etheridge, jr. Middle Devonian shales of Western New York. A cluster, $\times 12$, composed of vesicles one of which shows the punctate structure.
12. The excavation on the surface of a shell left by a species of *Terebricora*, $\times 10$, from the Miocene rocks of North Carolina.
- 13-14. *Cylindroecium dilatatum* Hincks. (13) Incrusting basal part of this recent species, $\times 12$, showing spinose dilatations at the base of the zooecia; (14) the erect zooecia, $\times 12$, attached to the tubular basal expansion.
15. *Avenella fusca* Dalzell, a living species, $\times 10$, illustrating the tubular stolons with the erect zooecia.
16. *Arachnidium hippothoides* Hincks. Part of the encrusting network of zooecia, $\times 10$, connected by slender fibers.
- 17-18. *Bowerbankia pustulosa* Ellis and Solander. (17) The erect zoarium, two-thirds natural size, showing the group of polypides at regular intervals; (18) a group, $\times 10$, with the polypides expanded. (Figs. 13-18, after Hincks.)

Among the living Ctenostomata *Alcyonidium* and related genera grow into soft incrustations or into masses 6 inches or more high in which the zooecia are closely united. In *Bowerbankia* the erect branching zoarium bears tufts of zooecia at regular intervals, while in *Amathia* an interesting spiral arrangement of the branches occurs. The Ctenostomata are typically marine, but a few genera have a tendency to live in estuaries. For this reason and other characteristics they are believed to have given origin to the exclusively freshwater Phylactolaemata.

ORDER 2. CYCLOSTOMATA.

The zooecia in this order are simple calcareous tubes, usually without transverse partitions, with a plain, rounded, uncontracted orifice not closed by an operculum. The walls are thin and minutely porous and do not show the complicated structures visible in the Cheilostomata or Trepotomata. The ovicell, when present, is an enlarged zooecium or an inflation of the zoarial surface. The zoarium assumes very many different forms of growth (pl. 3), although the method of growth is quite constant for a species.

Hitherto the families and genera of Cyclostomata have been founded almost entirely upon the form of the zoarium and the arrangement of the zooecia. As a result, very complicated artificial classifications have been proposed, which the reader may consult in the review given by Gregory in 1909.¹⁴

¹⁴ 1909. Gregory. Catalogue of Fossil Bryozoa in Department of Geology, British Museum, Cretaceous, vol. 2, pp. xxiv-xli.

The distinction between the families of Cyclostomata, like other orders of bryozoa, is or should be based on their larval forms, each family being characterized by a special larva. The larvae of the Cyclostomata are very similar to each other and difficult to discriminate, but fortunately they show their differences by the evolution of the embryos in ovicells of very different size, form, and position. The first tube of a zoarium is the ancestrula, and its lower part (pl. 4, fig. 1) is a dilated blisterlike form called the protoecium. It is in the protoecium that the histolysis of the fixed larva and its replacement by the first normal polypide living in the ancestrula occurs.

Without doubt the same principles of classification applied to the apparently more complicated Cheilostomata, as described on a later page, should be employed in the study of the Cyclostomata; indeed, a natural classification can be built up only by a study of the physiologic functions of the organs. In the Cheilostomata it will be noted that the form of the aperture and of the operculum, the presence of cardelles, and the modifications of the ovicell are the essential characters of generic and family classification. In the Cyclostomata the aperture is always more or less circular, the operculum and cardelles are wanting, leaving the ovicell as the single remaining essential character showing on the zooecia.

The value of the ovicell in the classification of the Cyclostomata is therefore of utmost importance, but unfortunately its study has been much neglected. Some species of Cyclostomata possibly did not develop ovicells, but the majority of them will after some search undoubtedly reveal specimens showing this organ. Indeed, one of the most interesting features in the study of the Cyclostomata is the search for ovicelled specimens among the many described species where now no ovicell is known. A beginning toward a natural classification of the Cyclostomata was made by Canu several years ago, and Canu and Bassler in 1920¹⁷ have amplified this subject. The student is referred to their work for more details and references to other researches upon the Cyclostomata. Some of the more common types of ovicell are figured on plate 4.

In spite of their general simplicity the Cyclostomata exhibit other features which can be used in connection with the ovicell in classification. For example, in many Cyclostomata there are accessory tubes developed either on the frontal or the dorsal side of the zoarium. These are zooecia, closed or open, which appear to be without a polypide. Thin sections of the zoarium are frequently necessary to determine the nature of such accessory tubes. The

¹⁷ 1920. Canu and Bassler. North American Early Tertiary Bryozoa. Bulletin 106, U. S. National Museum.

dorsal side of many branching forms is sometimes occupied by short tubes called *nematopores*, which appear at the surface as thread-like and in thin sections as narrow tubes upwardly directed. Somewhat similar tubes on the dorsal side grow in the opposite direction—that is, toward the zoarial base. These are the *firmatopores*. Certain Cyclostomata exhibit pores on the dorsal side as large as the polypide tubes, but with polygonal orifice. These are termed "*tergopores*." Somewhat similar pores on the frontal side, but covered by calcareous closures, are known as *dactylethrae*, while *cancelli*, another curious development on the frontal side, are cylindrical tubes closed by a finely perforated lamella and garnished in the interior with numerous spinules. Still other forms of tubes in this order are the ramifications of the polypidian tubes, termed "*vacuoles*" and "*mesopores*." The physiologic function of these various accessory tubes is still unknown, but they are constant in their development and are therefore of value in classification. Plate 4 exhibits the aspect of these various tubes both at the surface and in thin sections.

The method of division or gemmation of the zoecial tubes in the Cyclostomata is also quite important. In one method (peripheral) the tubes bifurcate at all heights and in all directions. In another method (oriented) gemmation occurs in a definite manner on a single or on two sides of a basal lamella or of an axial zone. Thin sections here again are indispensable in the study of this order.

Although many researches upon the Cyclostomata have been published, comparatively little attention has been devoted to the anatomy of the polypide, the study of its method of protrusion, and to the larval forms in addition to the ovicell. So far as known the ovicells contain numerous embryos, which have arisen by fission of a primary embryo developed from an egg.

The Cyclostomata commence in the Middle Ordovician and continue until the end of the Paleozoic era fairly well developed in number but of less importance than the two strictly Paleozoic orders, Trepostomata and Cryptostomata. In the Early and Middle Mesozoic they constitute the predominating order, but in the Cretaceous the Cheilostomata assume first place and continue so until the present. The Paleozoic forms have been described by Ulrich and other workers mentioned under the Trepostomata. The Mesozoic species have been the subject of numerous publications among which may be mentioned those by Gregory¹⁸ and by D'Orbigny.¹⁹ The Cenozoic Cyclostomata likewise have received much attention, as will be noted by consulting the monograph by Canu and Bass-

¹⁸ Gregory. Catalogue of Fossil Bryozoa in British Museum, Jurassic (1896), Cretaceous vol. 1, 1899, and Cretaceous vol. 2, 1909.

¹⁹ 1852. D'Orbigny. Paléontologie française, Terrain Crétacé, Vol. V.

ler of 1920. Hincks' British Marine Polyzoa (1880), Busk's Catalogue of Cyclostomatous Polyzoa in the British Museum (1875), and his Challenger Expedition Report (1886) as well as numerous papers by Waters, Smitt, Harmer, Canu, and other authors treat of the recent Cyclostomata.

The study of many Cyclostomata particularly those forming solid calcareous zoaria requires thin sections. The preparation of such sections is discussed in this article under methods of study.

In addition to the ovicells and other features just mentioned, the size of the orifices and the distances between them are important in specific identifications. Probably the simplest and most trustworthy method of identifying closely allied species is by the preparation of uniformly magnified photographs of the zoarial surface. The magnification of 12 and 25 diameters for the Cyclostomata has been found most useful and is recommended for comparative purposes.

ORDER 3. TREPOSTOMATA.

This order is limited to the Paleozoic era when it flourished in a wealth of species forming stony colonies which contributed largely to the formation of many limestone strata. These colonies were always calcareous and consist of masses, sometimes of considerable size, composed of long coherent, prismatic, or cylindrical tubes with terminal orifice. Each tube is composed of an inner or axial region with thin walls and an outer, peripheral zone with thicker walls and complicated structure. This change in the character of the tubes which gives the name to the order (*trepos*, change) is accompanied by the development of other features, namely, mesopores, acanthopores, more numerous diaphragms and similar structures of the more mature zooid.

The Trepostomata include the greater portion of the so-called Monticuliporoids which for a long time were regarded as corals, although their bryozoan nature was long insisted upon by Ulrich who published many proofs of their affinities to undoubted bryozoa. This relationship has been strengthened by the discovery by Cumings that the budding plan of certain Ordovician genera is precisely the same as in typical recent bryozoa, namely, that it consists of (1) a protoecium or minute circular disk, (2) the ancestrula, a tubular zoecium of the type seen in the Cyclostomata, and (3) several primary buds arising from and adjacent to the ancestrula. These primitive structures are separated from the rest of the colony by a considerable thickening of their posterior walls. In the corals, development from the larva is direct the moment it becomes sedentary and therefore the presence of the protoecium alone is practically conclusive as to the systematic position of the Trepostomata with the bryozoa.

Some of the Trepostomata are incrusting and consist of one or more superimposed layers, but most of them either rise into fronds and bifoliate expansions or form hemispherical to rounded masses of a size ranging as high as 2 feet in diameter. Such massive types of zoaria arise from the fact that the zooecia in the Trepostomata are directly superimposed upon one another to form the long tubes which by continued budding result in the branching or massive stony zoaria. These tubes are intersected by straight partitions (diaphragms) or curved ones (cystiphragms), which represent the covers and floors of successive layers. The diaphragms may be incomplete or provided with a central perforation. As a rule, they are few or wanting in the immature zone of the zooecia, but are more numerous in the outer or mature zone, where also the zooecia are often separated by more or less closely tabulated porelike spaces called mesopores. Zooecial covers with a small subcentral orifice may occur.

One characteristic of the Trepostomata, which, however, the order shares with the Cryptostomata, is the presence at regular intervals over the surface of elevated groups containing cells differing from the average in size (monticules) or spot-like areas (maculae) of such cells on a level with the zoarial surface or depressed below it. The size, shape, elevation, and distance apart of the maculae or monticules are usually specific characters. The monticules may vary from small sharp tubercles through rounded nodes to elevated rings completely encircling the zoarium while the maculae, although often inconspicuous spots on the surface, are sometimes quite distinct solid depressed areas or, as in one family, beautiful star-shaped regions.

The spine-like projections on the zooecial walls called acanthopores are found in thin sections to consist of minute tubes included in the wall substance, but with a definite structure of their own. These acanthopores traverse the mature region and undoubtedly represent structures with some definite function possibly like the avicularia or vibracular pores of the Cheilostomata.

For many years the identification of the Trepostomata was based upon external features such as the form of the zoarium, the shape of the zooecia, and such surface characters as the tubercles or maculae. This led to so much confusion that the order deservedly was not considered of much use in the identification of stratigraphic horizons. The internal structure of these stony forms gives the true specific characters, and so the preparation of thin sections for examination under the microscope has become indispensable in their study. However, when once a species has been thoroughly worked out it can generally be distinguished externally from associated forms of similar appearance by quite constant differences which often seem trifling and yet are doubtless of morphological importance. Even

the internal structure can be determined without the preparation of actual thin sections, for by smoothing the surface of the bryozoan and etching it slightly with acid most of the characters seen in tangential sections become visible. A similar procedure for the vertical section exhibits the internal characters very well. The aspect of the surface and the structure seen in thin sections of a few species of Trepostomata are illustrated in text figure 7. An outline of the

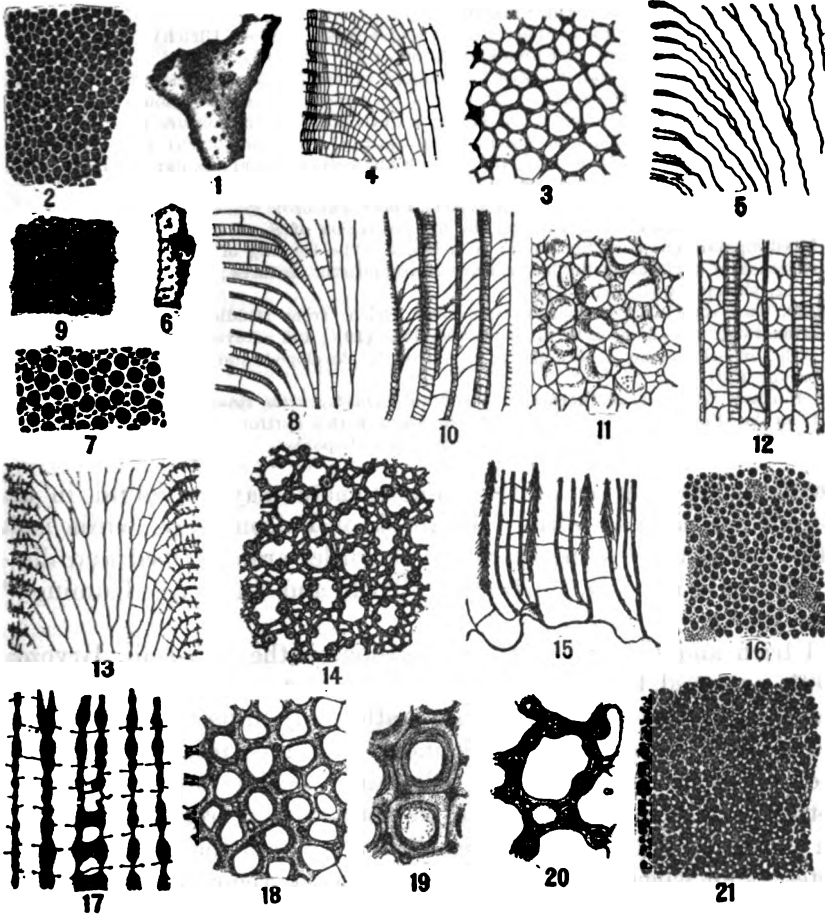


FIG. 7.—Structure of the Trepostomata.

- 1-4. Views of *Dekayella praenuntia* Ulrich, a common Middle Ordovician bryozoan, showing (1) the solid stony branch, \times two-thirds; (2) surface of the same, \times 6, with the spinellike acanthopores and thin zooecial walls; (3) a tangential section, \times 12, illustrating the same features in thin sections, and (4) a vertical section, \times 6, with few diaphragms in the immature zone to the right and numerous ones in the mature zone.
5. Longitudinal thin section \times 12, of an Ordovician species (*Hallopore crenulata* Ulrich) with crenulated zooecial tubes in which diaphragms are absent in both the mature and immature zones.
- 6-8. Views of an Ordovician species (*Hallopore pulchella* Ulrich) illustrating (6) a fragment, \times two-thirds, with tubercles developed at regular intervals on the surface; (7) the surface, \times 12, showing the zooecia and the intervening mesopores and (8) vertical section, \times 12, with numerous tabulae in the mesopores.

9. Surface of *Halopora multistabulata* Ulrich, $\times 12$, showing ornamented zoecial closures.
10. Vertical section, $\times 12$, of a discoid bryozoan (*Mesotrypa infida* Ulrich) from the Middle Ordovician shales of Minnesota, showing curved diaphragms in the zoecia and closely tabulated mesopores.
- 11-12. Internal structure of *Prasopora selwyni* Nicholson, a small hemispherical Ordovician bryozoan; 11, a tangential section, $\times 12$, exhibiting the zoecia and numerous mesopores; 12, a vertical section, $\times 12$, showing the isolation and semicircular form of the cystiphragms, the diaphragms, and the close tabulation of the mesopores.
13. Vertical section, $\times 6$, of *Hemiphragma irrasum* Ulrich from the Middle Ordovician shales of Minnesota, a solid branching bryozoan characterized by the occurrence of semidiaphragms in the mature region.
- 14-15. Structure of a thin laminar bryozoan (*Laoclema foliatum* Ulrich) from the Lower Carboniferous (Warsaw limestone) of Illinois; 14, tangential section, $\times 18$, exhibiting numerous mesopores and the zoecia indented by large acanthopores; 15, vertical section, $\times 18$, through the zoarium, showing a very short immature region and a development of numerous mesopores and strong acanthopores in the mature zone.
16. Surface, $\times 12$, of a ramose species (*Haloporella crenulata* Ulrich) from the Middle Ordovician shales of Minnesota, illustrating the occurrence at regular intervals of the clusters of mesopores termed maculae.
- 17-18. Thin sections of *Stenopora*, a typical Upper Paleozoic genus of the Trepostomata; 17, vertical section, $\times 12$, through the mature region of *S. americana* Ulrich, from the Mississippian (Keokuk limestone) of Illinois. The beading of the walls and the occurrence of perforated diaphragms are characteristic features; 18, tangential section, $\times 12$, showing wall structure.
- 19, 20. Two zoecia of *Batostoma winchelli* Ulrich, from Middle Ordovician shales of Minnesota, $\times 80$, as seen in tangential sections (19); and a variety of the same species, $\times 80$, in which the acanthopores are strongly developed and thin structure is apparent (20).
21. Surface, $\times 12$, of an incrusting bryozoan (*Atactoperella typicalis praecipua* Ulrich) from the Middle Ordovician shales of Minnesota, with a floriform aspect due to the indentation of the zoecial cavities by numerous acanthopores.

detailed classification of the Trepostomata may be found in the Eastman edition of Zittel's Textbook of Paleontology, while most of the genera and many species of the order are described and illustrated by Nicholson,²⁰ Ulrich,²¹ Ulrich and Bassler,²² Cumings,²³ and Bassler.²⁴

Ulrich and Bassler, in their Revision of the Paleozoic Bryozoa, 1904, proposed two divisions of the Trepostomata based upon the minute structure of the walls separating adjoining zooids. Of the seven families now recognized under the Trepostomata, four have the calcareous investment of adjoining zoecia amalgamated together so that one wall can not be distinguished from its neighbor. In the remaining three families the walls retain their duplex character, and when the zoecia are adjacent their boundaries are marked by a dark, divisional line. This line in all probability rep-

²⁰ 1881. Nicholson, H. A. The Genus Monticulipora.

²¹ 1882-1884. Ulrich, E. O. American Paleozoic Bryozoa, Journal Cincinnati Society of Natural History, vols. 5-7. 1890. Ulrich, E. O. Paleozoic Bryozoa, Geological Survey, Illinois, vol. 8. 1893. Ulrich, E. O. Lower Silurian Bryozoa, Geological Survey of Minnesota, Final Report, vol. 3, pt. 1.

²² 1904. Ulrich, E. O., and Bassler, R. S. Revision of the Paleozoic Bryozoa. Trepostomata. Smithsonian Miscellaneous Collections, vol. 47, pp. 15-55.

²³ 1908. Cumings, E. R. The Stratigraphy and Paleontology of the Ordovician Rocks of Indiana. Thirty-second Annual Report, Department of Geology and Natural Resources of Indiana, pp. 605-1190.

²⁴ 1911. Bassler, R. S. Early Paleozoic Bryozoa of the Baltic Provinces. Bull. 77, U. S. National Museum.

resents the fossilized remains of animal matter which filled this space during the life of the organism. Occasionally this narrow intervening area is occupied by a light-colored tissue, and in this case the outer boundaries of the wall of each zooecium can be seen. In certain genera of both divisions the amalgamation or the distinct character of the walls is difficult to determine, especially when mesopores are numerous, but if the zooecia are in actual contact there is little trouble in deciding the position of the particular form under study. Doubt has been cast upon the value of this differentiation in recent years, but even if the two divisions should not ultimately prove natural they are at least quite useful.

ORDER 4. CRYPTOSTOMATA.

In this order the zooecia are usually short and have their orifice concealed (*cryptos*, hidden) at the bottom of a tubular shaft or vestibule which is surrounded by a solid or vesicular calcareous deposit. The primitive zooecium is short and quite regular in its outline, being pyriform to oblong, quadrate or hexagonal with the aperture anterior. This same characteristic is shared by the Cheilostomata also and it is probable that the Cryptostomata are nothing more than Paleozoic Cheilostomata. The Cryptostomata differ, however, from the typical members of the Cheilostomata, first in having neither ovicells nor avicularia, second in the much greater deposit of calcareous material upon the front of the zooecia, third in the frequent development of successive layers of polypides, one directly over the other, thus forming a continuous tube, and fourth, in that whenever a zoarium attains an uninterrupted width of more than 8 millimeters it exhibits clusters of cells, differing more or less either in size or elevation from the average zooecia. The last two distinctions are suggestive of the Trepostomata, but the Cryptostomata differ chiefly in that the immature region (primitive cell) is usually much shorter and the passage to the mature region more abrupt, and that hemisepta occur at the bottom of the vestibule.

Some of the Cryptostomata are ramose and have long thin-walled prismatic tubes in the axial region, with or without diaphragms, precisely as in the ramose Trepostomata and Cyclostomata. They are distinguished from both these orders, however, by the presence of the hemiseptum, the incomplete plate which extends downward and forward from the posterior side of the base of the vestibule into the primitive cell. Sometimes a second hemiseptum is found springing from the bottom of the cell, in which case the latter is known as the inferior hemiseptum and the former as the superior one. The purpose of the hemisepta is unknown, although it is possible that they served as supports for a movable operculum.

The relationship of the Cryptostomata to the Cheilostomata is further suggested in the zoarial forms they assume and in the beauty of the surface of the zooecia. In the typical Cryptostomata the zoarium consists of two thin layers of zooecia growing back to back into erect sword-shaped, ramose, ribbonlike or fan-shaped expansions. In other Cryptostomata the zoaria form lacelike expansions consisting of only a single layer of cells with the reverse side covered by a dense layer of striated or minutely granulose tissue. In the remaining sections of the order the zoaria are ramose with the zooecia arising from a real or imaginary axis and opening on all sides of the cylindrical stems. Usually the zoaria are continuous, but in some of the bifoliate and ramose forms they are divided into segments, articulating with each other.

Most of the Cryptostomata can be identified from the zooecial surface characters, but in some of them, particularly the bifoliate and solid ramose species, thin sections are as essential as in the Trepostomata. On account of their geometrical regularity of zooecial form, thin sections of the Cryptostomata are often most beautiful objects under the microscope.

The order commences in Early Ordovician times, reaches its greatest development in the Devonian and Mississippian, and becomes extinct at the close of the Permian. Typical examples of the order are illustrated in text figure 8. Many of the Ordovician genera and species were described and illustrated by Ulrich in 1893²⁵ and Bassler in 1911,²⁶ the Silurian by Bassler in 1906,²⁷ the Devonian by Hall and Simpson in 1887,²⁸ and the Carboniferous by Ulrich in 1890.²⁹

ORDER 5. CHEILOSTOMATA.

The Cheilostomata, characterized by the closure of the aperture by a chitinous lip or operculum when the polypide is retracted, included most beautiful objects from an esthetic standpoint because usually in this order the frontal wall of the zooecium is composed of calcite assuming often the most delicate and sometimes bizarre patterns. Until recently the differences in these patterns were relied upon for the discrimination of genera and species, with the result that a most unnatural classification prevailed. The calcification of the frontal wall is only one of the functions of the bryozoan and a natural classification should be based upon all the important fea-

²⁵ 1893. Ulrich, E. O. Lower Silurian Bryozoa of Minnesota, *Geology of Minnesota*, vol. 3, pt. 1.

²⁶ 1911. Bassler, R. S. The Early Paleozoic Bryozoa of the Baltic Provinces. *Bulletin* 77, U. S. National Museum.

²⁷ 1906. Bassler, R. S. The Bryozoan Fauna of the Rochester Shale. *Bulletin* 292, U. S. Geol. Survey.

²⁸ 1887. Hall and Simpson. Corals and Bryozoa. *Paleontology of New York*, vol. 6.

²⁹ 1890. Ulrich, E. O. Paleozoic Bryozoa. *Geological Survey, Illinois*, vol. 8.

tures. The Cheilostomata exhibit the highest type of development in the bryozoa and for that reason the description of the various functions of the animal has been reserved for this place. The living bryozoan shows that these functions in the order of their importance are first those dealing with reproduction, namely, with the

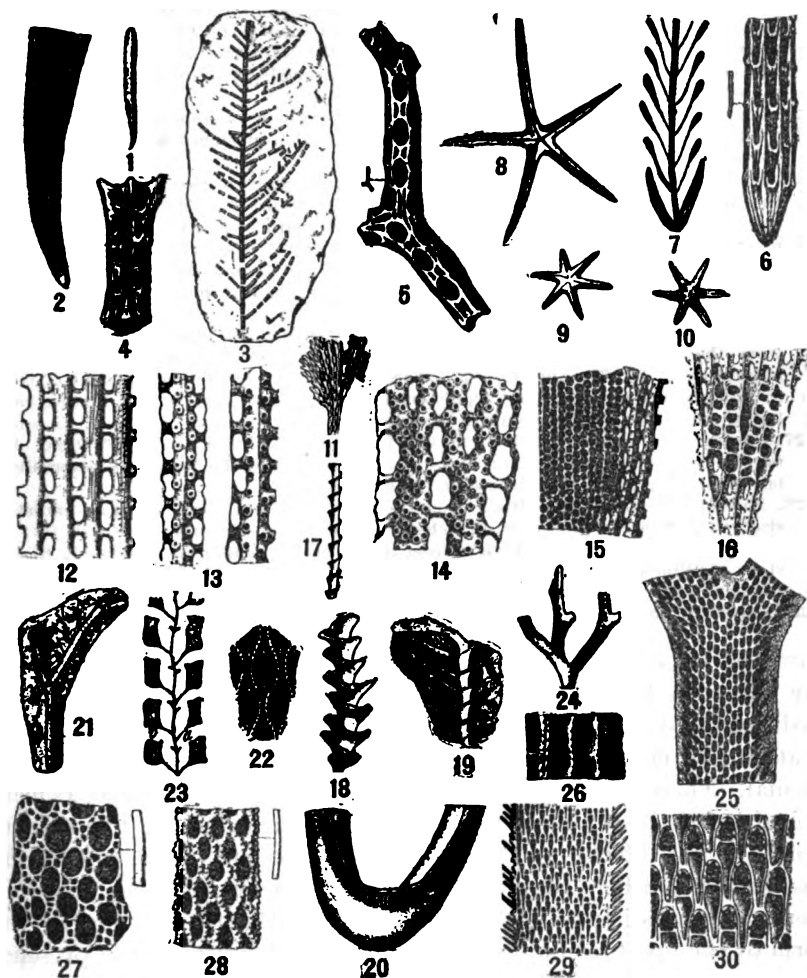


FIG. 8.—Cryptostomata.

- 1-2. *Escharopora subrecta* Ulrich. Middle Ordovician (Black River) shales of Minnesota. A typical member of the Cryptostomata. 1. The narrow bifoliate zoarium, two-thirds natural size, with a pointed striated base which fits into a corresponding socket attached to other objects. 2. Surface of the basal part of a specimen, $\times 6$.
- 3-4. *Arthroclema billingsi* Ulrich. Ordovician (Trenton) limestone, Ottawa, Canada. 3. Zoarium composed of numerous joints articulating with each other, two-thirds natural size. 4. A single joint or segment, $\times 12$, of a related species (*A. cornutum* Ulrich) with a socket for articulation on top and the pointed basal articulating process at the bottom.
5. A threadlike bryozoan of this order (*Nematopora ovalis* Ulrich) natural size and $\times 12$, from the Middle Ordovician shales of Minnesota.

- 6-7. *Helopora spiniformis* Ulrich. Ordovician (Lebanon) limestone of Central Tennessee. 6. One of the jointed segments natural size, and the lower portion of the same, $\times 18$. 7. Longitudinal thin section of the same species showing the short immature region and the thickened mature zone.
- 8-10. Cryptostomata with star shaped zoaria, two-thirds natural size, often mistaken for fossil star fishes. 8. A five-rayed form (*Evactinopora quinqueradiata* Ulrich) from the Lower Carboniferous (Burlington) limestone of Iowa. 9, 10. Two views of a six-rayed form (*E. searadiata* Meek and Worthen) from the same locality.
- 17-19. *Arohimides*, a characteristic Lower Carboniferous bryozoa, two-thirds natural size, in which the lacelike cell-bearing zoarium similar to *Fenestella* is wound around a solid spiral axis. Specimens (17, 18) with the celluliferous portion broken away are most frequently found but occasionally more of the frond is preserved (19).
20. Another characteristic Lower Carboniferous bryozoan (*Lyropora*) in which the solid support is lyre shaped with the lacelike portion stretched between two supports.
- 21-23. A typical member of the Cryptostomata (*Arthropora simplex* Ulrich) from the Middle Ordovician (Black River) shales of Minnesota, showing several segments, two-thirds natural size, preserved in their natural position (21), the ornamentation of the zoecial surface, $\times 22$ (22) and a vertical section $\times 12$, illustrating the typical internal structure of the Cryptostomata (23), namely, the short boxlike immature zone with its hemisepta and the thickened mature zone with the zoecial aperture (a) at the base of the vestibule (v).
- 24-26. A bifoliate ribbonlike cryptostomatous bryozoan (*Rhindiolyta mutabilis* Ulrich) from the middle Ordovician shales of Minnesota. 24. A specimen, two-thirds natural size. 25. The surface, $\times 12$, showing the very regular arrangement of the zoecia characteristic of the Cryptostomata. 26. Several zoecia still further enlarged and illustrating the surface ornament.
27. *Streblotrypa herzeri* Ulrich from the Lower Carboniferous rocks of Ohio. A narrow rambose zoarium, natural size and $\times 12$, simulating Trepostomata externally but having the internal structure of the Cryptostomata.
28. *Rhombopora ohioensis* Ulrich from the Lower Carboniferous of Ohio, natural size and $\times 12$, a representative of a characteristic Upper Paleozoic genus.
- 29-30. *Worthenopora spinosa* Ulrich, from the Lower Carboniferous (Warsaw) limestone of Illinois, showing possible relationship of the Cryptostomata to the Chelostomata. 29. A view of the bifoliate branch $\times 9$, illustrating the spinose margin. 30. Zoecia of the same, $\times 28$, showing the Chelostomatous type of zoecia.

passage of the eggs and the escape of the larvae, or, in other words, the relations between the operculum and the ovicell; second, the hydrostatic system and extrusion of the polypide, and lastly, calcification and chitinization, or the nature of the skeletal part of the animal. Therefore the least important of these functions has as mentioned before been almost invariably alone considered. These functions are not difficult to determine in the recent forms, but in the fossil species, where only the calcareous skeleton remains, it would seem sometimes impossible to discover all of them. Fortunately the form of the aperture indicates the hydrostatic function, the presence of cardelles or projections on the apertural wall reveals the movements of the operculum, and the nature and position of the ovicell illustrates the function of reproduction.

Function of reproduction.—A permanent classification of the bryozoa is impossible at present, because each family is undoubtedly characterized essentially by its larva and unfortunately the larval form is known at present in only a few families. The fertilized eggs of the bryozoan are transformed into embryos and these into larvae

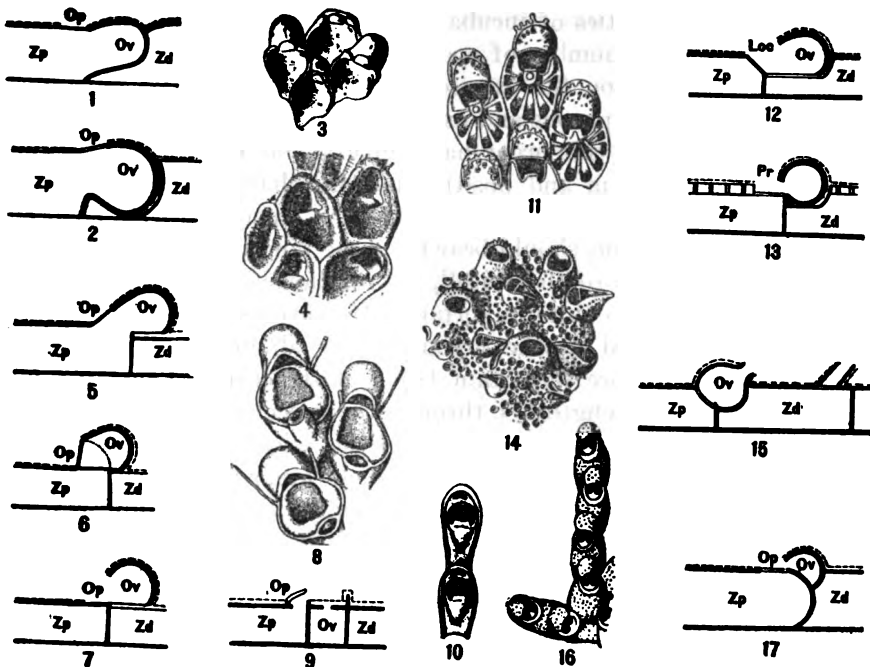


FIG. 9.—Ovicell structure in the Chelostomata. Op=Operculum; Ov=ovicell; Zd=distal zooecium; Zp=proximal zooecium; Loc=locella; Pr=peristome or tube developed by growth of peristome. The thin broken line indicates the membranous ectocyst, while the thin double line represents the operculum.

- 1-2. Longitudinal sections through zooecia with an endosooecial ovicell. The ovicell is within the zooecium itself and the operculum closes both the zooecium and the ovicell. In 2 a fold of the zooecial wall separates the ovicell from the zooecium.
3. *Micropera coriacea* Esper. A group of zooecia, $\times 25$, with two showing the endosooecial ovicell and the operculum closing the ovicell as well as the zooecia.
4. *Velumella levinsoni* Canu and Bassler. Zooecia, $\times 40$, with the two uppermost bearing the small endosooecial ovicell.
- 5-7. Sections showing three types of hyperstomial ovicell in which the ovicell is placed on the distal zooecium. In 5 the ovicell opens below the operculum, and there is thus only one aperture. In 6 there are two apertures, and the operculum in opening closes the ovicell. In 7 the ovicell opens above the operculum.
8. Three ovicelled zooecia of *Ramphonotus minas* Busk, $\times 50$, illustrating the hyperstomial form of ovicell.
9. Sketch of endotoichal ovicell in which the ovicell is completely separated from the zooecium and its orifice is removed from the aperture and placed in the same plane.
10. Two zooecia, $\times 50$, of *Cellaria sinuosa* Hassall, showing the apertures of the small endosooecial ovicell in advance but on the same plane as the large zooecial apertures.
11. Ovicelled zooecia, $\times 86$, of *Umbonula verrucosa* Esper with hyperstomial ovicell opening largely above the aperture.
- 12-13. Hyperstomial ovicells. In 12 the ovicell is placed in a deep cavity of a distal zooecium. The operculum is very oblique and operates in a special chamber or locella. 13 represents a special type in which the ovicell opens above the operculum in the peristome or tube formed by the growth of the peristome.
14. A group of zooecia, $\times 23$, of *Tubiporella magnirostris* MacGillivray, with two peristomial ovicells.
15. Diagram of a peristomial ovicell showing its formation by an enlargement of the peristome.
16. Typical example (*Phylactella labrosa* Busk) of the recumbent ovicell, $\times 80$, in which the ovicell is placed on the distal wall of the zooecium itself.
17. A sketch of a recumbent ovicell showing its relations to the zooecia and operculum.

within special cavities of incubation which, when visible, are called ovicells. A large number of species of Cheilostomata show no ovicells and nothing on the exterior reveals their mode of reproduction. Some are oviparous and expel their eggs by an intertentacular organ, but most of this order have some visible ovicell. An ovicell of a particular form and position usually characterizes all of the genera of a family, and it is of course an invariable rule that all the species of a genus should bear the same kind of ovicell. In addition to the position of the ovicell, the relationship of the operculum to the ovicell is also quite important. Its various methods of operation are illustrated in the accompanying diagram, which shows sketches of the more important types of structure. (Text fig. 9.) A section passing lengthwise through the zooecia or individual cells is necessary to determine the nature of the ovicell as well as the general structure. This section requires much care, as the specimen must be mounted on edge and the abrasion must follow a definite row of cells. By the use of small wire nippers it is easy to trim the specimen to just the right form, then by mounting it in hardened balsam between two small bits of wood (fragments of a match serve excellently) to hold it on edge, the abrasion can be continued until the desired section is obtained. Actual dissection of the specimens with a fine needle under the microscope is often necessary, especially to determine the nature of the ovicell.

Hydrostatic function.—The discovery of the zooecial hydrostatic function by Jullien in 1888 explained many manifestations of the bryozoan which for a long time had remained absolutely unknown. This function of the extrusion of the polypide is so important that the two suborders of the Cheilostomata, the Anasca and Ascophora, are based upon it. In the suborder Anasca the so-called compensation sac is wanting and the polypide is extruded from the zooecium through the depression of the chitinous frontal wall by parietal muscles. This feature, as well as the general anatomy of the polypide in this order, is illustrated in text figure 10. In the Ascophora the polypide can emerge from the zooecium only if an equal volume of water is introduced to compensate for the extrusion. For this purpose the compensation sac (text fig. 11) or compensatrix is placed beneath the dorsal under the larger part of the zooecial length and communicates with the aperture. At the moment of extrusion of the polypide, muscles attached to the compensation sac contract, thus enlarging the sac, and the operculum in opening for the extrusion of the polypide frees its orifice. A minute drop of water then penetrates into the sac, thus compensating for the polypide. The entrance of the water into the compensation sac is thus the hydrostatic function and it is exercised in many ways which

are indicated by the nature of the frontal and of the operculum. The nature and shape of the operculum is thus very important and whenever possible the student should make a special study of this organ.

Operculum.—This small chitinized organ closes at the same time both the orifice of the polypide and of the compensation sac, its anterior part, or *anter*, closing the former and the posterior part, or

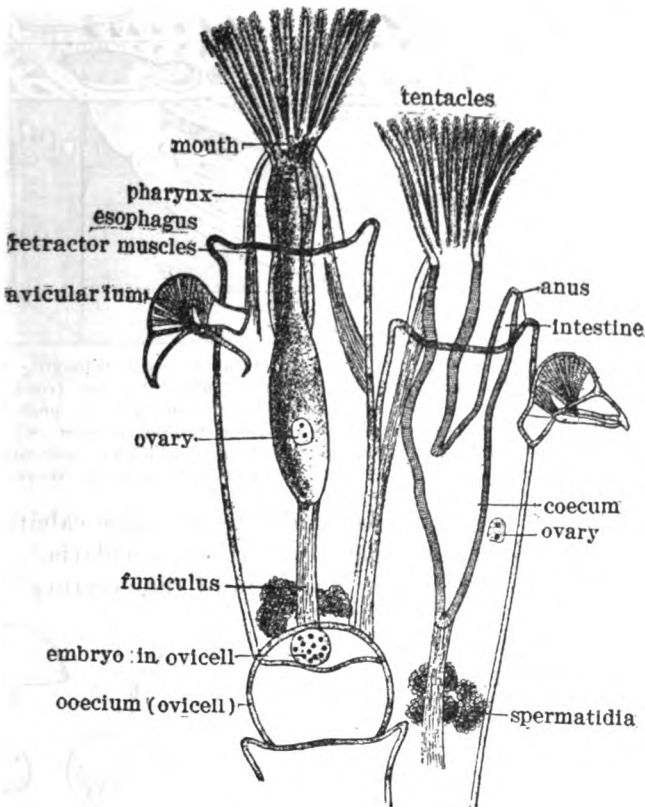


FIG. 10.—General anatomy of the Chelostomata. Two zooids of the common corneous chelostomatous bryozoan (*Bugula stictularia* Linnaeus) from the Atlantic, showing the various parts of the polypide, highly magnified. (After Parker and Haswell.)

poster, similarly closing the latter. Thus the shape of these two portions is evidence of the nature of the tubes they close and the determination of the operculum is an important feature. (Text fig. 12.) In one large group of the Ascophora the orifice of the compensation sac is very small and the operculum has a corresponding small narrow tongue; in another group this orifice is quite large and the corresponding portion of the operculum is large; again a special tube, the spiramen (text fig. 13), may introduce the water into the com-

pensatrix. Finally, the compensation sac may not end in the aperture at all, but may open exteriorly by a special pore, the ascopore.

The form of the operculum is therefore in most cases identical with that of the aperture, but the latter on fossil forms is not always

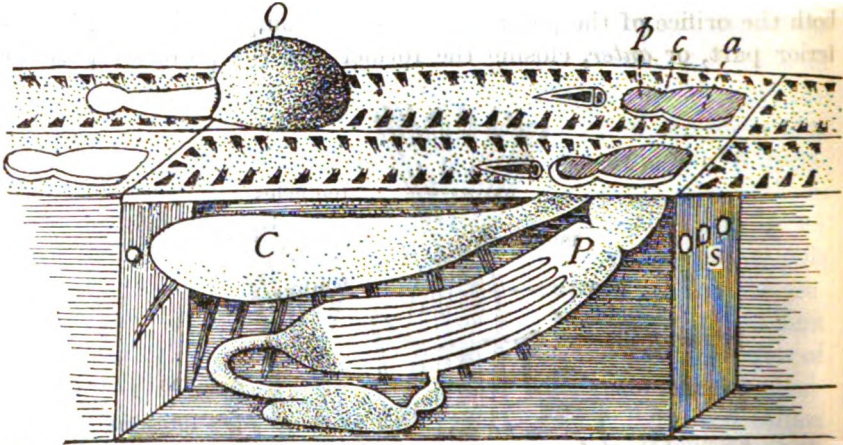


FIG. 11.—Diagrammatic drawing of a Chelostomatous bryozoan belonging to the sub-order Ascophora, showing the ovicell (O), the ornamental calcareous frontal wall with a spear-shaped avicularium and the form of the operculum with its posterior portion (p), which leads into the compensation sac (c), the anterior portion (a) closing the orifice of the polypide (P). The hinge or cardelle upon which the operculum operates is shown at o and the communication pores or septulae, between the zooecia, at s.

visible exteriorly, for it may be hidden by excessive calcification of the frontal or by exterior organs such as the avicularia. The only safe means of determining the true form of the aperture is the ex-

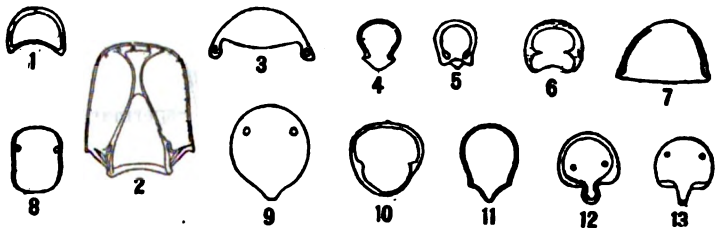


FIG. 12.—Opercula. Sketches showing the operculum in different genera of Chelostomata.

1-3. Anasca, no compensation sac (1, *Thalamoporella*; 2, *Steganoporella*; 3, *Aspidostoma*).

4-13. Ascophora, illustrating the variations in form of the anterior portion of the operculum (anter) through which the polypide emerged and the posterior part (poster) by which water was introduced into the compensatrix. (4, *Trypostega*; 5, *Triphyllusoon*; 6, *Smitina*; 7, *Holoporella*; 8, *Stichoporella*; 9, *Bipora*; 10, *Peristomella*; 11, *Schismopora*; 12, *Rhynchosoon*; 13, *Schismopodrella*.)

amination of the interior of the zooecium obtained by abrasion of the basal surface. This preparation is easily made by mounting the fragment to be studied in hard Canada balsam on a glass slip, cellu-

liferous side down, and then rubbing away the superfluous material until the inner side of the calcified frontal wall is revealed when the true nature of the frontal unchanged by any external influence may be found.

The preparation of the operculum, which remains only on recent forms of course, is another important and quite simple operation. The simplest way to prepare slides for viewing under the microscope is to scrape off a few zooecia with the operculum in place, crush these carefully in a drop of water on the slide and after drying add Canada balsam and a cover glass. Some of the opercula will be

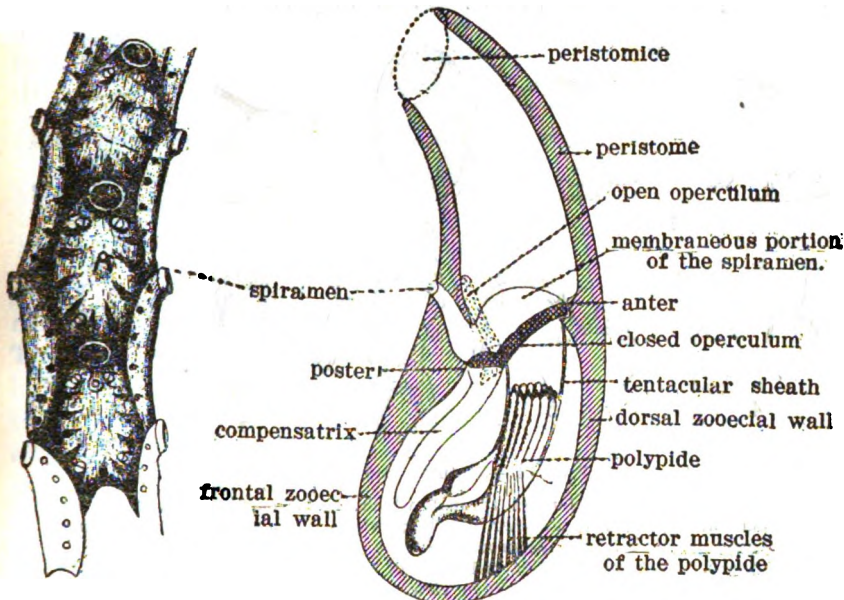


FIG. 13.—Structure of the Ascophora. *Tessardoma gracile* Sars. A recent species of the Ascophora showing a zoarial branch, $\times 60$, and a drawing of a longitudinal section through a single zooecium with the various parts of the zooecium and polypide indicated. (After Hincks and Jullien.)

broken by this crude method, but enough perfect specimens will remain to make the saving of time worth while.

Formation of the zoarial skeleton.—The living tissue of the bryozoan giving rise by its differentiation to all the various organs is a delicate epithelial membrane, the endocyst, lining the interior of the skeletal parts. The first differentiation of the endocyst is the ectocyst, a thin outer covering membrane which has no secreting power. Next, the endocyst secretes the mesenchyme, which in turn gives origin to the polypide and other portions of the organism.³⁰ The calcareous or chitinous secretion forming the zoarial skeleton occurs be-

³⁰ 1900. Calvet, L. Contributions a l'histoire des bryozoaires ectoproctes marins. Travaux de l'Institut Zoologie de l'Université de Montpellier, new ser., Memoire No. 8.

tween the ectocyst and endocyst and with all of its variations in structure and accompanying organs, such as vibracula and avicularia, is a result of the activity of the endocystal buds. The walls of the zoarial skeleton may consist simply of a smooth thin calcareous deposit, the olocyst, or above this may be secreted a second very porous layer, the tremocyst, intimately joined with the olocyst, although sometimes clearly detachable. A third layer, the pleurocyst, consisting of a granular deposit with lateral punctations, may also occur. The pores of these several layers are traversed by mesenchymatous fibers which likewise pass from zoecium to zoecium through the lateral walls by small pores called septulae. These may be uniporous or multi-

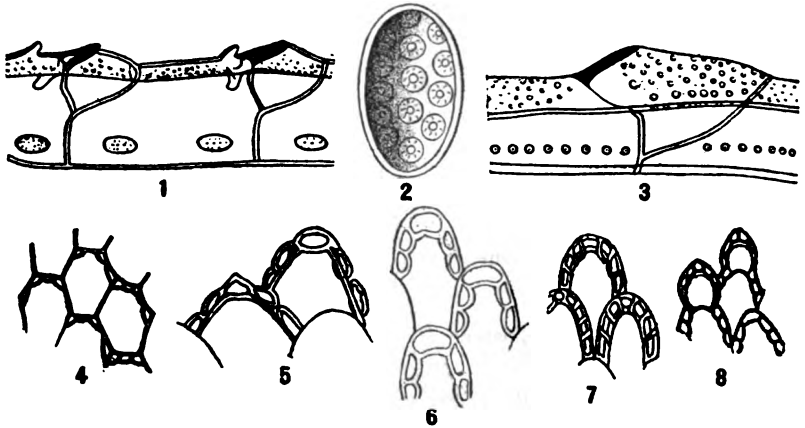


FIG. 14.—Septulae and diatellae.

- 1-3. Septulae or parietal pores through which the mesenchymatous fibers pass from one zoecium to another. 1. Edge view of a zoecium of *Cheltopora sincera* Smitt with multiporous septulae developed (=rosette plates of authors). 2. A greatly enlarged view of a multiporous septula illustrating details of the structure. 3. Edge view, $\times 23$, of portions of two zoecia of *Hippopodina fegeensis* Busk showing uniporous septulae through the lateral walls.
- 4-8. Diatellae or pore chambers. Views of various species of Chellostomata magnified, as seen from the basal side and illustrating the variation in aspect of the diatellae. 4. *Peristomella prestans* Hincks. 5. *Ellisia levata* Hincks. 6. *Callopora lineata* Linnaeus. 7. *Cauloramphus spinifer* Norman. 8. *Trypostega venusta* Norman.

porous (text fig. 14), but before reaching the septulae the mesenchymatous fibers traverse small lateral chambers in the proximal part of the zoecium, called diatellae or pore chambers.

The discrimination of the characteristics of these various zoecial skeletal features is important in the determination of genera and species, and so it is necessary in study that the following preparations be made. First, thin sections of the wall, particular the frontal, are needed to illustrate the characters of the three layers, olocyst, tremocyst, and pleurocyst. Second, the frontal must be abraded away to show the occurrence of such structures as diatellae. This abrasion is effected by mounting the specimen, frontal side up, in Canada balsam

on a slide and after heating to harden the balsam rubbing it gently on a soft bone.

Avicularia and vibracula.—The “bird’s head” organ or avicularium (text fig. 15) attached to the zooecia of many Cheilostomata consists of a small cell containing a rudimentary polypide and of a

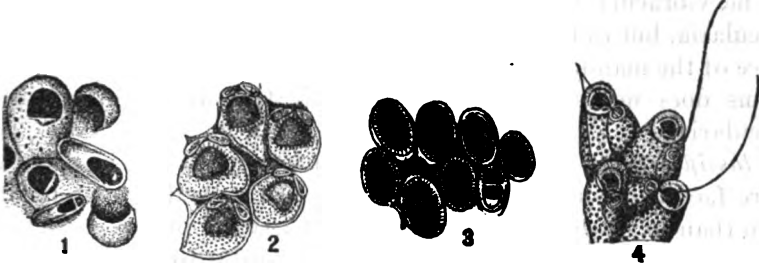


FIG. 15.—Avicularia and Vibracula.

1. *Holoporella descostillei* Savigny-Audouin, $\times 25$, with large avicularia preserving bar on which the mandible operates.
2. *Antropora granulifera* Hincks, $\times 30$. The avicularia are small and developed in pairs just above the aperture.
3. *Grammella crassimarginata* Hincks, $\times 30$, in which the avicularia are very similar to the zooecia but may be distinguished by the occurrence of the bar.
4. *Mastigophora hyndmanni* Johnston, $\times 30$. Zooecia preserving the long vibraculum and the pore from which it emerges. (After Hincks.)

mobile chitinous mandible which in life keeps up a snapping motion. The latter peculiarity led to the belief that the purpose of the avicularia was one of defense, but it is more probable that they have something to do with alimentation or oxygenation. The mandibles are symmetrical objects corresponding to the opercula of normal zooecia

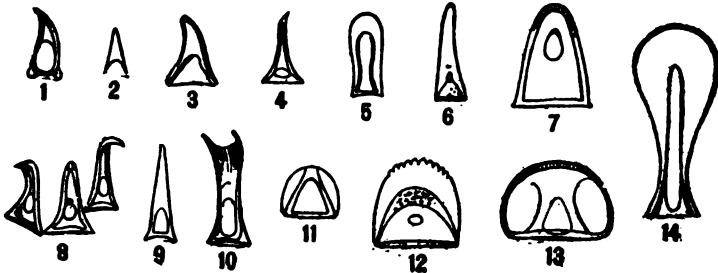


FIG. 16.—Mandibles.

Various types of this chitinous portion of the avicularium, magnified, which is useful in the identification of cheilostomatous bryozoa. 1, *Adonellopsis*; 2, *Smittina*; 3, *Peristomella*; 4, *Schizopodrella*; 5, *Smittina*; 6, *Retepora*; 7, *Holoporella*; 8, *Retepora*; 9, *Adona*; 10, *Triphyllosoon*; 11, *Thalamoporella*; 12, *Smittina*; 13, *Umbonula*; 14, *Thalamoporella*.

and like them varying in shape with the species, so that the determination of their size and shape is as essential in detailed work as that of the opercula. Their preparation for study under the microscope is the same as for the opercula, already described; indeed, the two will almost always be found on the same slide. Some of the variations in the form of the mandibles are illustrated in text figure 16.

They usually have a straight proximal edge, which works against a calcareous bar, or, when this is not complete, from two teeth. In the fossil forms and in many dead specimens of recent species the mandible has been lost, but its position is clearly indicated on the porelike spaces left by the avicularia in well-preserved specimens.

The vibracula (text fig. 15) are modified zooecia, similar to the avicularia, but differing in the occurrence of a long cilium or seta in place of the mandible. The porelike excavation it leaves in the fossil forms does not show the variation of structure observed in the avicularia.

Classification.—From the foregoing discussion it will be noted that more factors enter into the determination of a cheilostomatous bryozoan than in those of any other order. First the presence or absence of a compensation sac must be learned in order to place the species in its proper suborder (*Anasca* or *Ascophora*). Then the relationship between the operculum and the ovicell and, again, between the operculum and the compensatrix, the position of the ovicell, the form of the aperture, the nature of the frontal wall, which may be chitinous or, when calcareous, may be smooth (olocyst), punctate (tremocyst), or radiately ribbed (pleurocyst), the occurrence of dietellae and septulae, and of avicularia and vibracula, as well as other more detailed structural features which have not been discussed in this article, are to be observed in turn. The proper description and illustration of a species of Cheilostomata is a considerable task in itself, which can not be accomplished simply by publishing a diagrammatic figure of the zooecial surface characters.

Formerly the classification of the Cheilostomata was based on purely zoarial features, but in the latter half of the nineteenth century the zooecial characters were more closely studied, especially by Busk,³¹ D'Orbigny,³² Smitt,³³ and Hincks.³⁴ The latter author considered especially the form of the aperture—in other words, only the hydrostatic system—but Jullien³⁵ in various publications emphasized the more important characters for consideration. The microscopic anatomy of the polypide in the Cheilostomata is described and illustrated in detail in Calvet's important contribution in 1900.³⁶ Various

³¹ Busk George. Catalogue of Marine Polyzoa in Collection British Museum. Cheilostomata (1852); Polyzoa collected by H. M. S. *Challenger*, Pt. 1. Cheilostomata, Vol. X, Pt. XXX (1884), and various articles entitled "Zoophytology in the Quarterly Journal Microscopical Science from 1855 to 1867.

³² D'Orbigny, Alcide. Paléontologie française, Terrain Crétacé, Vol. V, 1852.

³³ Smitt, F. A. Kritisk förteckning öfver Skandinavien's Hafsbyrzoer. Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar, vols. 22 to 24 (1865-1867) and vol. 28 (1871).

³⁴ Hincks, Thomas. British Marine Polyzoa (1880).

³⁵ Jullien, Jules. Mission Scientifique du Cap Horn, 1882, 1883, Vol. VI, Zoologie, Bryozoaires (1888).

³⁶ Calvet, L. Contributions à l'histoire des bryozoaires ectoproctes marins. Travaux de l'Institut Zoologique de l'Université de Montpellier, new ser., Mem. No. 8, 1900.

works on the structure of the Cheilostomata have been issued by Harmer, and Waters since 1878 has been a most important contributor to this subject. His many memoirs on both Cenozoic and Recent bryozoa likewise are of the highest value. In 1909 Levinsen³⁷ published a memoir which is indispensable to the modern student.

The fossil Cheilostomata also form the subject of numerous researches, among which the work on Cretaceous faunas by D'Orbigny and various monographs on the Tertiary of Europe,³⁸ Africa,³⁹ and South America⁴⁰ by Canu and of North America⁴¹ by Canu and Bassler should be mentioned. The last-named work contains numerous text figures illustrating family and generic structure, in addition to detailed references to the literature.

DISTRIBUTION OF THE BRYOZOA.

The continent of North America is undoubtedly the most favored part of the earth for reading Paleozoic history, and it is equally favored for the study of fossil bryozoa, as many of the Paleozoic marine limestone and shale formations abound in these organisms. The Eurasian land mass presents many surface exposures of Paleozoic age, but they are to a greater or less extent disconnected, and the fossil forms are not so well known as in America. In Asia the Salt Range of India has yielded Carboniferous bryozoa, while in Europe the region of the Ural Mountains and the areas bordering on the Baltic Sea, England, and Scotland contain most of the Paleozoic strata which have thus far afforded specimens. Three or four times as many species have been made known from the Paleozoic of North America as from all the rest of the world.

The earliest undoubted bryozoan is a species of the peculiar trepostomatous genus *Nicholsonella*, occurring in the Canadian rocks of Arkansas, although a species referred doubtfully to the Ctenostomata has been described from the Ungulite sandstone of Early Ordovician age in Esthonia. The limestones and shales of the various divisions of the Ordovician above the Canadian abound in stony bryozoa of the Cryptostomata and Trepostomata (pl. 1, fig. 1), although the Cyclostomata are represented and an occasional species of Ctenostomata may be found. In the Silurian, bryozoa are not so common, and the

³⁷ Levinsen, G. M. R. Morphological and systematic studies on the Cheilostomatous Bryozoa (1909).

³⁸ Canu, F. Bryozoaires des terrains tertiaires des environs de Paris. *Annales de Paléontologie*, tomes 2 (1907), 3 (1908), 4 (1909), and 5 (1910).

³⁹ Canu, F. Etude comparée des Bryozoaires Helvétiques de l'Egypte avec les Bryozoaires vivants de la Méditerranée et de la mer Rouge. *Mémoires de l'Institut Egyptien*, tome VI, 1912.

⁴⁰ Canu, F. Iconographie des Bryozoaires fossiles de l'Argentine. *Anales del Museo Nacional de Buenos Aires*, tomo XVII (1908), tomo XXI (1911).

⁴¹ Canu and Bassler. North American Early Tertiary Bryozoa. *Bulletin* 106, U. S. National Museum, 1920.

Cryptostomata developed at the expense of the Trepostomata. In the Devonian and Carboniferous the Trepostomata became much reduced in numbers and finally disappeared, while the Cryptostomata formed a wealth of species, especially of the lacelike *Fenestella* (pl. 1, fig. 2) and its allies. The Ctenostomata remain as sparsely represented as before, but the Cyclostomata have increased in number by the development of the great family Fistuliporidae.

With the beginning of the Mesozoic a decided change occurs in the bryozoa. The Cryptostomata and Trepostomata have disappeared entirely, the Ctenostomata are as rare as before, but the Cyclostomata now develop great numbers of species, with zoaria quite similar in many instances to the Paleozoic Trepostomata. The Cyclostomata remain the predominating type until Upper Cretaceous time, when the Cheilostomata, which appear in the Jurassic, now expand into so many species that they soon attain supremacy. D'Orbigny alone has described not less than 537 species of Upper Cretaceous Cyclostomata and 300 Cheilostomata, although many of these are synonyms. This great development of the bryozoa in the Mesozoic is known only in European strata, for in North America and in other parts of the world these rocks have yielded comparatively few bryozoan faunas.

Both North America and Europe are noted for their Cenozoic bryozoan faunas. The Atlantic and Gulf coastal plains of North America and the northern and southern slopes of the Alps, as well as numerous other localities in Europe, are rich in bryozoa with the Cheilostomata and Cyclostomata well represented and the former predominating. Southern Australia likewise affords an abundant Tertiary bryozoan fauna.

In the recent seas the Cheilostomata, exhibiting the bryozoa at the highest stage of their perfection and beauty, is the predominating order and numerous species have been described from all the oceans where they occur, usually in abundance, from tide level down to great depths. The voyage of the *Challenger* brought forth a wealth of species which has since been greatly augmented by various expeditions, as well as by the activity of local collectors. The seaweed tossed up so abundantly along certain coasts is a fertile collecting place for many parasitic species of Cheilostomata and Cyclostomata.

STRATIGRAPHIC VALUE.

The use of fossil bryozoa in stratigraphic work has scarcely attained the importance it deserves. In American Paleozoic strata they are preeminently the fossils to be relied upon in correlation work. They are nearly always abundant, and even when poorly preserved exteriorly can be identified by thin sections. Crinoids and

crustaceans are usually too scarce; mollusca, abundant in some formations, are almost wanting in others, and likely to be poorly preserved; vertebrate remains are too few, and usually local in distribution. The brachiopods are also usually abundant in all Paleozoic strata, but have commonly too great a range vertically to be trustworthy guides in close work.

In the Mesozoic rocks of America bryozoan faunas are few and so far little known, but in Europe they assume an importance equally as great as the Paleozoic faunas in America. In both continents the Cenozoic faunas are abundant and of great value for correlative purposes. In North America over 1,000 Cenozoic species are known, while in Europe the number is equally large.

Because to the unaided eye there seems little variation of form among the bryozoa, they have been generally neglected by collectors and geologists. Early writers are also to some extent responsible for this neglect, for they failed to discriminate the different species, and made a few names, such as *Chaetetes lycoperdon*, *Stenopora fibrosa*, etc., serve for a multitude of diverse forms. It is no doubt true, and this is another cause for the neglect of the bryozoa, that their discrimination does require good powers of observation and careful, often tedious, study. Furthermore, the number of species is great. Somewhat more than 1,500 species have been described from American Paleozoic formations, yet these are probably but a half or a third of the distinguishable forms present and already largely known to specialists in the subject. The determination, at least the first determination, of the species often, and among the Trepostomata nearly always, requires the preparation of microscopic sections, a tedious operation at best. However, when once a species has been thoroughly worked out, it can generally be distinguished externally from associated forms of similar appearance by quite constant differences, which often seem trifling and yet are doubtless of morphological importance. These various considerations would seem to compel greater labor for the mastery of the bryozoa than for any other class, but accurate determination of the brachiopods, corals, graptolites, and other more widely studied groups requires equally great efforts.

In spite of numerous researches on the bryozoa as a whole, a beginning only has been made in the work of determining the geographical distribution of species and genera and of elucidating the many obscure questions regarding the migration of faunas in the ancient as well as in the modern seas, their extinction or evolution, their reappearance and like phenomena. Similarly the study of the larval forms, the anatomy of the polypide, and of the various subjects concerned in the relationship between the polypide and the zoecium offers a wide field of research.

EXPLANATION OF PLATES.

PLATE 1.

FIG. 1.—Limestone slab, natural size, composed mainly of Trepostomata or stony bryozoa. Middle Ordovician, St. Paul, Minnesota.

FIG. 2.—Surface of limestone, $\times 2$, from the Lower Carboniferous (Warsaw) limestone at Columbia, Illinois, exhibiting the remains of lacelike bryozoa (*Fenestella* and *Polypora*) of the order Cryptostomata.

PLATE 2.

FIG. 1.—Bryozoan marl from the Early Tertiary rocks of South Carolina. The figure to the left ($\times 2$) represents the rock as exposed by weathering and the one to the right the appearance of the specimens ($\times 2$) after preparation for study.

FIG. 2.—Dredgings from the vicinity of the Philippine Islands showing various types of recent cheilostomatous bryozoa, natural size, in a more or less fragmentary state.

PLATE 3.

Growth forms in the Cyclostomata.

FIG. 1.—A typical encrusting linear species *Stomatopora pratti* Canu and Bassler, $\times 4$, from the Eocene (Jacksonian) of North Carolina. A second, very minute, species of *Stomatopora* is also present.

FIG. 2.—Portion of the zoarium of *Stomatopora polygona* Canu and Bassler, $\times 4$, illustrating tendency of the branches to form polygons.

FIG. 3.—A fragment of Early Silurian stony bryozoa (Cryptostomata) with an encrusting cyclostomatous species, *Corynotrypa turgida* Ulrich, and the latter magnified, $\times 6$, to show the curious club-shaped zooecia.

FIG. 4.—Another species of encrusting Cyclostomata, *Corynotrypa inflata* Hall, $\times 6$, introduced for comparison with the preceding to show how these simple species differ from each other.

FIG. 5.—A common, recent bryozoan, *Oristia*, magnified, consisting of erect tuftlike zoaria made up of articulated segments with the zooecia arranged in two rows. The prominent ovicell is present.

FIG. 6.—Another recent jointed bryozoan, *Oristia cornuta* Ellis, $\times 16$, with uniserial zooecia.

FIG. 7.—Noncelluliferous side of an erect, much-branched zoarium, *Hornes frondiculata* Lamouroux, from the recent seas.

FIG. 8.—Celluliferous side of *Discosparea marginata* D'Orbigny, magnified, from the Cretaceous of France, showing subcolonies in various stages of growth.

FIG. 9.—A pear-shaped zoarium, *Lichenopora franquana* D'Orbigny, magnified, from the Cretaceous rocks of France.

FIG. 10.—A recent fungiform bryozoan, *Fasciculipora ramosa* D'Orbigny, from South Patagonia, slightly magnified.

FIG. 11.—Lateral view of *Idmonea magnireversa* Canu and Bassler, $\times 8$, from the Eocene (Jacksonian) of North Carolina, showing the zooecial openings on one side of the branch only.

FIG. 12.—Another branching species, *Mecynoecla cylindrica* Canu and Bassler, $\times 8$, from the Eocene rocks of North Carolina, in which the apertures open on all sides of the zoarium.

FIG. 13.—A branching species, *Zonopora cottaldina* D'Orbigny, magnified, from the Cretaceous of France, with the zooecial apertures and mesopores arranged in regular zones.

FIG. 14.—Magnified view of a solid ramose species, *Multicavea magnifica* D'Orbigny, from the Upper Cretaceous of France.

FIG. 15.—A solid ramose bryozoan, *Tretocychoecia attenuata* Ulrich, x 8, from the Lower Eocene (Midwayan) of Arkansas, with mesopores and a zoarium as in the Trepotomata, but possessing the ovicell (broken) of the Cyclostomata.

FIG. 16.—A composite zoarium, *Centronea (Multitubigera) micropora* Reuss, enlarged, from the Eocene rocks of Northern Italy.

FIG. 17.—A very common, simple ramose species of Cyclostomata, *Mecynoecia proboscidea* Milne-Edwards, x 8, from the Tertiary (Vicksburgian) rocks of Alabama.

FIG. 18.—Another branching species, *Spiropora majuscula* Canu and Bassler, x 8, from the Eocene of South Carolina, showing the arrangement of the apertures in regular rows.

PLATE 4.

Structural features of the Cyclostomata.

FIG. 1.—Zoarium of *Stomatopora parvipora* Canu and Bassler, x 12, from the Eocene rocks of Mississippi showing the orbicular protoecium from which the first zooecium or ancestrula develops.

FIG. 2.—Drawing of a recent, bilinear, encrusting species, *Peristomoecia (Stomatopora) divergens* Waters, enlarged, in which the free portion of the tube enlarges to form the ovicell.

FIG. 3.—A recent encrusting species, *Oncousoecia (Tubulipora) lobulata* Hincks, magnified, with the axis of the ovicell parallel to the tubes.

FIG. 4.—An ovicelled branch, x 6, of a fossil species, *Idmonea grillator* Canu and Bassler, from the Eocene rocks of Alabama, showing the ovicell on the celluliferous side.

FIG. 5.—Ovicelled example of *Tervia irregularis* Meneghini, x 6, illustrating the position of the ovicell on the dorsal, noncelluliferous side, characteristic of the family Terviidae.

FIG. 6.—Ovicelled zoarium, x 10, of the recent species *Tubulipora flabellaris* Fabricius.

FIG. 7.—The characteristic ovicell of the family Macroeciidae Canu, x 6, in which the oeciostome or opening of the ovicell is unusually large.

FIG. 8.—Basal side of an ovicelled zoarium of a discoidal species, *Discocyrtis eudesi* Michelin, x 3, from the Cretaceous rocks of France. The ovicells (some of them broken) form a regular circle about the base.

FIG. 9.—A portion of the jointed colony of *Crisia* showing the characteristic ovicell in the family Crisiidae.

FIG. 10.—A common recent and fossil bryozoan, *Mecynoecia (Entalophora) proboscidea* Milne-Edwards, x 6, illustrating development of the ovicell parallel to the tubes.

FIG. 11.—A recent encrusting species *Plagioecia patina* Lamarck, x 6, exhibiting position of ovicell at right angles to the direction of the zooecia, characteristic of the family Plagioeciidae.

FIG. 12.—The ovicell of *Partretocychoecia porosa* Canu and Bassler, x 6, from the Eocene rocks of South Carolina, showing characteristics of the Tretocychoeciidae, a family of the Cyclostomata with mesopores and other features resembling the Trepotomata.

FIGS. 13-15.—Tergopores. 13. Longitudinal thin section of *Pleuronoe subpertusa* Canu and Bassler from the Eocene of Mississippi, x 12, illustrating the structure of the tergopores (to the right) and the zooecial tubes. 14. Lateral side of the zoarium, x 6, showing oblique arrangement of the apertures. 15. Dorsal side of the zoarium, x 6, illustrating the large tergopores.

FIGS. 16-18.—Vacuoles. 16. Dorsal side, x 12, of *Hornera frondiculata* Lamouroux showing the vacuoles at the base of longitudinal sulci. 17. Celluliferous side of the same species, x 12. 18. Longitudinal thin section, x 12, of *Hornera antarctica* Waters showing vacuoles on both the frontal (to the left) and dorsal sides.

FIGS. 19-21.—Cancelli. 19. An ovicelled specimen of *Lichenopora rudecta* Audouin, x 12, showing the zooecial apertures in regular rows separated by the cancelli. 20. Longitudinal thin section, x 12, of *Lichenopora goldfussi* Busk. The cancelli are the superposed and ramified tubes. 21. Portion of a zoarium of *Lichenopora holdsworthi* Busk, x 12, illustrating the spinules in the cancelli.

FIGS. 22-24.—Dactylethrae. 22. Dorsal side of a branch, x 12, of *Brkosones admota* Canu and Bassler, from the Eocene (Jacksonian) of North Carolina exhibiting the dactylethrae. 23. A longitudinal thin section of *Brkosones semota* Canu and Bassler, x 12, showing zooecial tubes to the left and dactylethrae to the right. 24. Celluliferous side of *B. admota* Canu and Bassler, x 12.

FIGS. 25-27.—Firmatopores. 25. Lateral view of a branch of *Idmidronea culter* Canu and Bassler, x 6, from the Eocene (Jacksonian) of North Carolina showing the openings of the zooecial tubes in the upper right hand corner and the remainder of the branch covered with firmatopores. 26. Longitudinal thin section, x 12, of *I. coronopus* Milne-Edwards, illustrating structure of firmatopores (to the right) and zooecial tubes. 27. Celluliferous surface of *I. rosacea* Canu and Bassler, x 12, from the Eocene (Jacksonian) of North Carolina, exhibiting the zooecial apertures and the firmatopores.

FIGS. 28-29.—Nematopores. 28. Longitudinal thin section, x 12, of *Diplo-desmopora opposita* Canu and Bassler, from the Cretaceous rocks of France showing the zooecial tubes to the right and nematopores to the left. 29. An ovicelled branch of the same species, x 6, showing lateral position of the ovicell and the nematopores on the basal (right) side.

FIGS. 30-31.—Mesopores. 30. Longitudinal thin section of *Tretocydoecia reticulata* Canu and Bassler, x 6, showing the formation of the numerous mesopores in this species. 31. A zoarium of this species, x 6, from the Eocene (Jacksonian) of South Carolina illustrating the resemblance at the surface between the zooecia and mesopores.



FIG. 1.

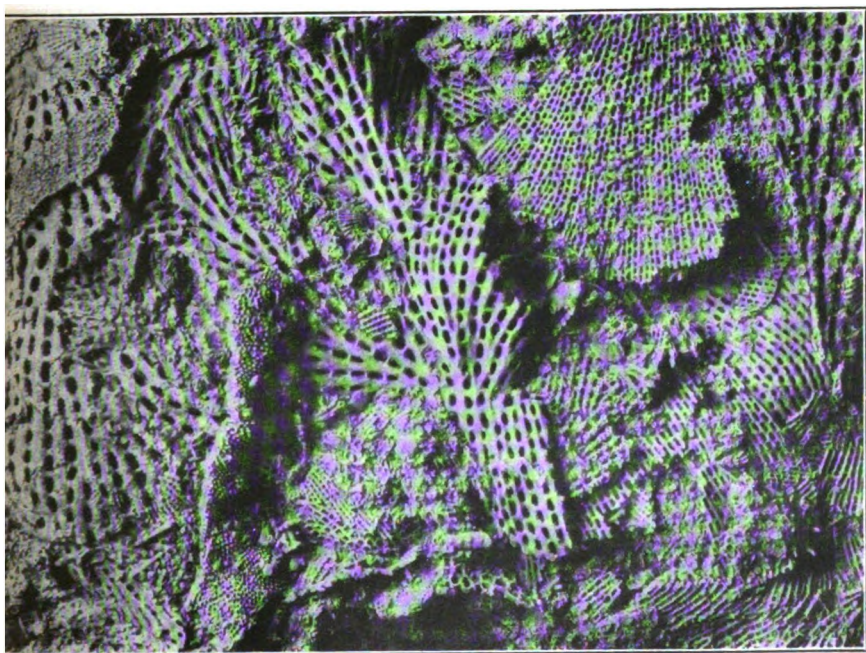


FIG. 2.

FOR EXPLANATION SEE PAGE 378.

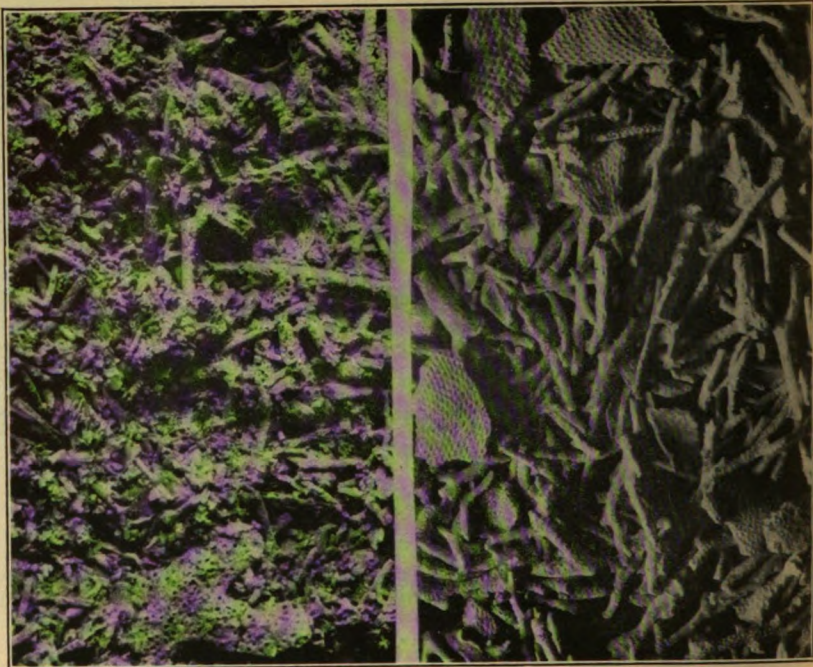


FIG. 1.

FIG. 2.

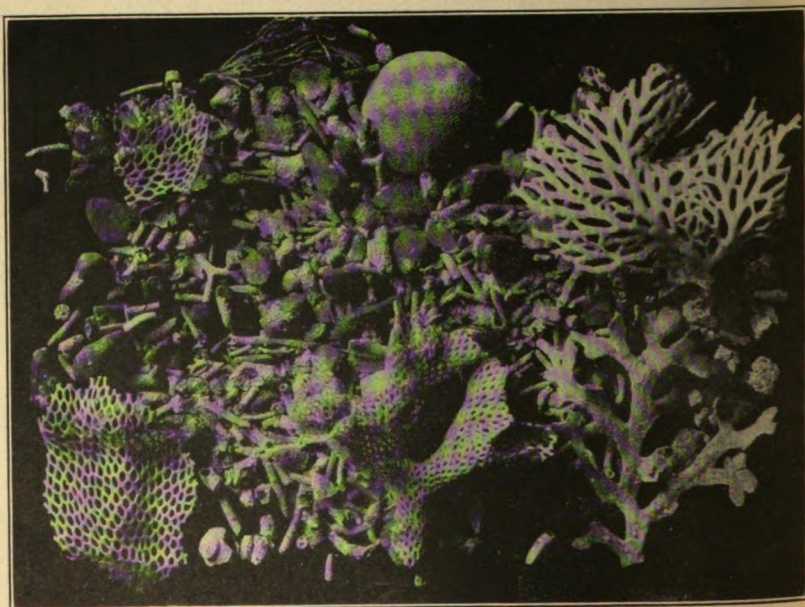
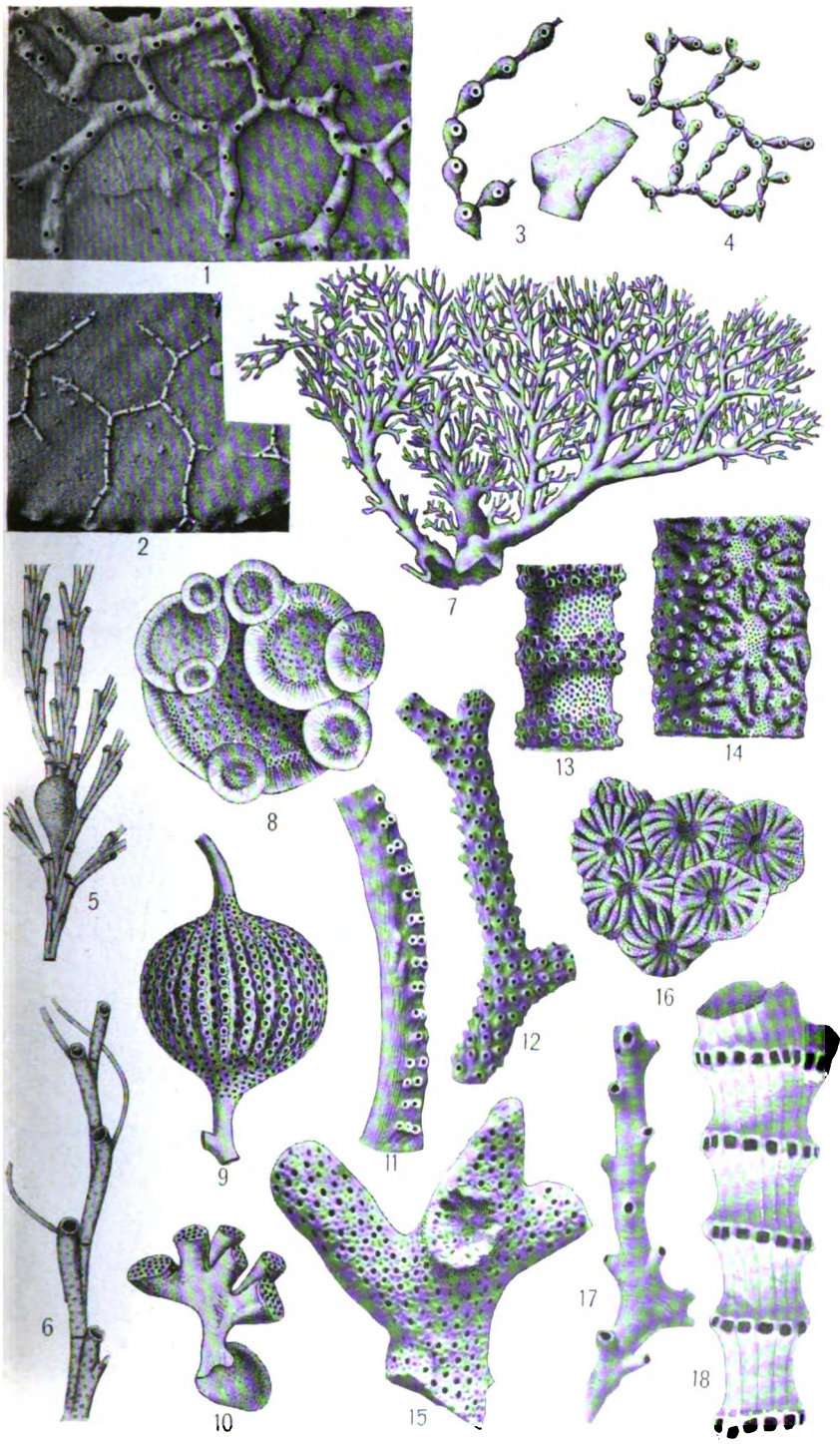
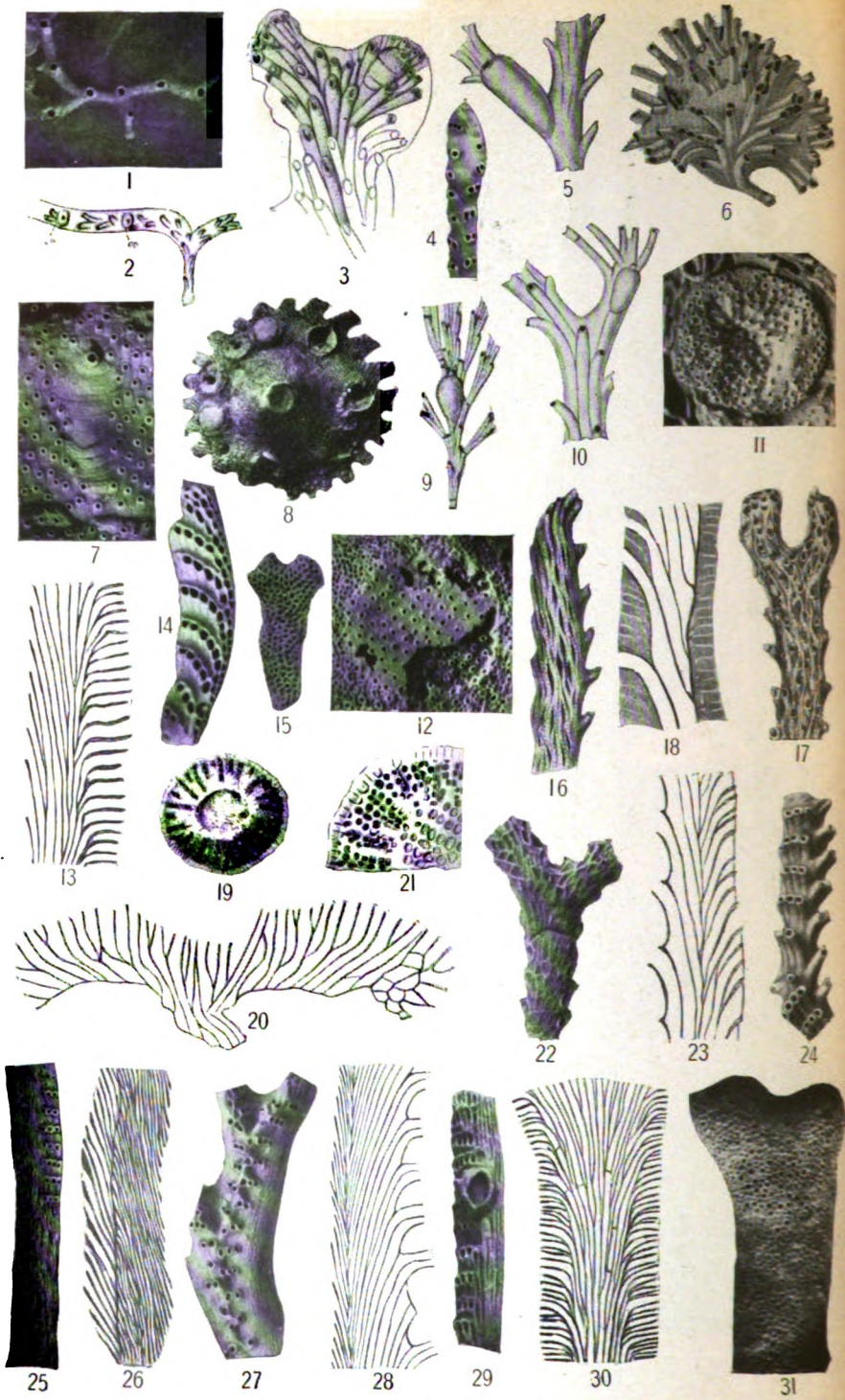


FIG. 3.

FOR EXPLANATION SEE PAGE 373.



FOR EXPLANATION SEE PAGE 378.



FOR EXPLANATION SEE PAGE 379.



Proceedings of the Paleontological Society

PROCEEDINGS OF THE THIRTEENTH ANNUAL MEETING
OF THE PALEONTOLOGICAL SOCIETY, HELD AT AM-
HERST, MASSACHUSETTS, DECEMBER 28-30, 1921.

R. S. BASSLER, SECRETARY

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R. S. BASSLER, *Secretary*

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SESSION OF WEDNESDAY, DECEMBER 28

The general session of the Society, for the presentation of annual reports and other business, scheduled for 2 p. m., Wednesday, December 28, was postponed until Thursday, at 9.30 a. m., in order that the members could attend the section of the Geological Society of America where the stratigraphic and paleontologic papers forming Group B were being read.

Wednesday evening the members participated in a smoker at College Hall with the Geological Society of America and affiliated societies and listened to the address of Prof. J. F. Kemp, its retiring President.

SESSION OF THURSDAY, DECEMBER 29

President Stanton called the thirteenth annual meeting of the Society to order at 9.30 a. m., December 29, in the geological lecture-room of Geology-Biology Building. The first matter of business was the report of the Council.

REPORT OF THE COUNCIL

To the Paleontological Society, in thirteenth annual meeting assembled:

Two meetings of the Council have been held during the year, one following the last annual meeting and the other immediately preceding the present session, all other business having been transacted by correspondence. The Council's administration of the Society's business for the thirteenth year is presented in the following reports:

SECRETARY'S REPORT

To the Council of the Paleontological Society:

The proceedings of the twelfth annual meeting of the Paleontological Society, held at Chicago, Illinois, December 28-30, 1920, are printed in volume 32, number 1, pages 119-156, of the Bulletin of the Geological Society of America, printed March 31, 1921, and distributed to the members.

The announcement that the thirteenth annual meeting of the Society would be held at Amherst, Massachusetts, December 28-30, 1921, as the guest of Amherst College, and the Council's proposed nominations for officers for 1922 was issued February 22, 1921.

Membership.—The Society has lost two of its Correspondents by death during the year—Dr. Henry Woodward, of the British Museum and editor of the Geological Magazine for over 50 years, and Dr. Alfred

Nathorst, of the Royal Natural History Museum, Stockholm, geologist, Arctic explorer, ethnologist, and probably the most eminent student of paleobotany. We have also suffered the loss of one member, Mr. John T. Doneghy. One member has resigned during the year. Four new members have just been elected and three additional nominations are awaiting consideration at the present meeting. This year five of our members have been elected to fellowship in the Geological Society of America. The result of these various changes leaves a total number of members at the end of 1921 as 212.

Publications.—Eight papers published by the Society in the Bulletin of the Geological Society of America, in addition to the Proceedings, have been distributed to the members during the course of the year. With favorable action of the Council, the Secretary has distributed to members elected in recent years a considerable number of duplicate copies of papers printed in the earlier years of the Society.

Respectfully submitted,

R. S. BASSLER,
Secretary.

WASHINGTON, D. C., December 27, 1921.

TREASURER'S REPORT

To the Council of the Paleontological Society:

The Treasurer begs to submit the following report of the finances of the Society for the fiscal year ending December 24, 1921:

RECEIPTS

Cash on hand December 22, 1920.....	\$468.68
Membership fees.....	282.55
Interest, Connecticut Savings Bank.....	23.51
	<hr/> \$974.74

EXPENDITURES

Secretary's office:

Secretary's allowance.....	\$50.00
Office expenses.....	57.74
Clerical help.....	25.00
	<hr/> \$132.74

Treasurer's office:

Treasurer's allowance.....	\$25.00
Printing and postage.....	13.25
	<hr/> 38.25

Geological Society of America:

Printing programs, etcetera.....	\$10.50
Reprints.....	115.08
	<hr/> 125.48

Pacific Coast Section:

Assessment for the American Association for the Advancement of Science.....	5.00
	<hr/> 302.47
Balance on hand December 24, 1921.....	\$872.27
Net increase in funds.....	\$3.59
Outstanding dues (1921), 7.....	21.00

Respectfully submitted,
(Signed)

RICHARD S. LULL,
Treasurer.

NEW HAVEN, CONNECTICUT, *December 24, 1921.*

APPOINTMENT OF AUDITING COMMITTEE

President Stanton appointed Messrs. Raymond and Cushman as a committee to audit the Treasurer's accounts, following the reading of the Council's report.

ELECTION OF OFFICERS AND MEMBERS

The result of the Ballots for the election of officers for 1922 and of new members was then announced, as follows:

OFFICERS FOR 1922

President:

W. D. MATTHEW, New York City

First Vice-President:

E. S. RIGGS, Chicago, Ill.

Second Vice-President:

E. W. BERRY, Baltimore, Md.

Third Vice-President:

B. L. CLARK, Berkeley, Calif.

Secretary:

R. S. BASSLER, Washington, D. C.

Treasurer:

RICHARD S. LULL, New Haven, Conn.

Editor:

WALTER GRANGER, New York City

NEW MEMBERS

WALTER SCOTT ADKINS, Bureau of Economic Geology, Austin, Texas.

ANTONIO PASTOR GIRAUD, care Transcontinental de Petroleo, S. A., Tampico, Mexico.

A. S. ROMER, Department of Geology, Columbia University, New York City.

ARTHUR J. TIEJE, Department of Geology, University of Colorado, Boulder, Colorado.

NEW NOMINATIONS AND ELECTION TO MEMBERSHIP

Three nominations to membership which had arrived too late for the printed ballot and which had received the approval of the Council were then presented to the Society:

Miss ALVA C. ELLISOR, A. B. University of Texas, paleontologist of the Humble Oil and Refining Company, 803 Humble Building, Houston, Texas. Proposed by B. L. Clark and Chester Stock.

FRED WILLIS DARBY, engaged in care and preparation of the Marsh collection of fossil vertebrates since 1908, Peabody Museum, Yale University, New Haven, Connecticut. Proposed by R. S. Lull, Charles Schuchert, and C. O. Dunbar.

FRANK HARRIS MCLEARN, Ph. D. Yale (1917), associate invertebrate paleontologist, Geological Survey of Canada, Ottawa, Canada. Proposed by Charles Schuchert, E. M. Kindle, and R. S. Lull.

It was then voted that the By-Laws be suspended and that the vote of the Society for the election to membership of these three nominees be cast by the Secretary.

There being no further business, the Society proceeded to the reading of scientific papers in general session, with President Stanton in the chair.

PRESENTATION OF PAPERS

The first paper on the program, dealing with the molluscan genus *Salterella* and showing its possible cephalopod affinities, was presented by the author and illustrated by drawings. Discussion by Messrs. Foerste, Ulrich, and Chadwick.

NATURE OF *SALTERELLA*

BY THOMAS H. CLARK

(Abstract)

Since 1863 the genus *Salterella* has been included in the class Pteropoda, although its position there has always been in some doubt. A large collection of specimens from Lévis, Quebec, has enabled the writer to make a more or less thorough study of these little fossils. Although in some specimens ex-

ternal shells are present, the individuals consist for the most part of septa placed one within the other, the larger of which possess a "septal neck." This, in connection with other characteristics, has led the writer to the conclusion that in *Salterella* we have the most primitive cephalopod known. The relation of *Salterella* to *Volborthella* is considered and a revision of the species of *Salterella* is submitted.

An interesting account of recent cephalopods and of the possible habits of these animals, and also of the trilobites, was given in the next paper, presented by the author and illustrated with many well selected lantern slides. Discussion by Messrs. Foerste and Clarke.

POSSIBLE HABITS OF CEPHALOPODS AND TRILOBITES

BY PERCY E. RAYMOND

(Abstract)

Knowledge of the anatomy of trilobites has become sufficiently full to allow a reasonable speculation as to the mode of life and habits of these animals. Many writers have made suggestions, and the more plausible have been brought together and illustrated by drawings which are the work of Mr. Charles Fish, of Providence, Rhode Island.

Less has been written upon the cephalopods, but a comparison of the shells of Recent and Paleozoic forms and a study of the anatomy and habits of the modern nautilus suggest certain possible reconstructions. The importance of the shell in the economy of the animal is emphasized.

In the absence of the author, the next paper was read by the Secretary and discussed by Dr. Clarke.

HISTORICAL SKETCH OF PALEOPATHOLOGY

BY ROY L. MOODIE

(Abstract)

Pathological conditions on the fossil bones of extinct animals were first recognized and described among the Pleistocene mammals, especially the cave mammals of Europe.

The earliest reference to pathological conditions of this nature was made by E. J. C. Esper, a professor in the university of Erlangen, in 1774. He referred to an injured femur of a cave bear, interpreting the lesion as an osteosarcoma. Eighty years later Mayer concluded that the injury was an infected fracture with considerable callus. Goldfuss, von Soemmering, and Cuvier in 1820-23 drew many interesting conclusions concerning the habits of the extinct mammals, based on their observations of the injuries. William Clift in 1823 read a paper to the Royal Society of London describing certain injured and diseased bones of bovine animals. These specimens are said to be still preserved in the Hunterian Museum.

The first memoir devoted entirely to paleopathology was not by a paleontologist but by a surgeon, von Walther of Bonn. The Natural History Museum

of Bonn had acquired a number of bones of Pleistocene mammals, some of which exhibited interesting lesions. Von Walther published his memoir in 1825, and was much impressed by the undoubted evidences of disease, thousands of years old, which he very carefully described. His interpretations of these remains were confirmed seventy years later by the eminent pathologist, Rudolph Virchow.

Ten years later (1835) the subject was further advanced by P. C. Schmerling, a Belgian paleontologist, who wrote and illustrated the finest memoir thus far produced relating to paleopathology. His material was chiefly Pleistocene mammals. A physician, Mayer, in 1854 produced the next important contribution, in which he reviewed all the preexisting literature. His results were accompanied by fine lithographic plates. The studies of Virchow in 1870 and later in 1895 were likewise devoted to remains of Pleistocene mammals.

So far, the literature of paleopathology was of European origin entirely. Except for incidental references to pathological conditions by Leidy, Osborn, Hatcher, Volz, Schlosser, Wieland, Lull, Gilmore, and others, no definite attempt was made to advance the science of paleopathology of extinct animals until 1912, when Abel reviewed the whole field in his work on *Paleobiologie*. Abel deserves the credit of perceiving a new field of work on the pathology of vertebrate fossils—a field which had already been cultivated in America among the invertebrates by Clarke.

In 1913 the entire subject received the impetus of Ruffer's genius. He saw the whole field as one, and combined for the first time observations on ancient man, as seen in the Egyptian mummies, and extinct animals. The field of study involved in the subject of paleopathology thus includes the Paleozoic invertebrates, among which disease may have had its inception, the fossil vertebrates, and ancient man. To these interesting fields of observation Sudhoff of Germany and Escamel of Peru have recently added observations on ancient surgical instruments, which have been recently shown to be the cause of certain types of ancient pathology. The subject thus merges with the history of medicine.

The Secretary then presented the following paper for the author and called attention to the algal nature of a specimen of the much-discussed fossil *Oldhamia* which was exhibited.

OLDHAMIA IN THE LOWER CAMBRIAN OF MASSACHUSETTS

BY B. F. HOWELL

(Abstract)

Specimens, apparently referable to the much-discussed and variable Irish fossil, *Oldhamia* (*Murchisonites*) *antiqua* (Forbes), have recently been collected from the purple shales of one of the well known Lower Cambrian exposures of Pearl Street, Weymouth, Massachusetts, by Mr. Stinson Lord, of Quincy, who has presented them to the Paleontological Museum of Princeton University. They are well preserved and seem almost certainly to be referable to some form of alga, and not to be mere inorganic markings. This

species was first described from Ireland more than half a century ago, but the exact age of the beds containing it there has never been definitely determined. The fact that the shales in which it occurs at Weymouth are of Lower Cambrian age argues for a similar age for the Irish beds.

Another problematical organism formed the subject of the next paper, presented by the author and illustrated by specimens. Discussion by Messrs. Chadwick, Ulrich, Moore, and Clarke.

NATURE OF TAONURUS AND ITS USE IN ESTIMATING GEOLOGIC TIME

BY J. J. GALLOWAY

(Abstract)

Taonurus is regarded as the burrow of a sedentary worm which lived in brackish water on a growing delta. *Taonurus caudagalli* is a structure which appears in vertical sections of the Esopus grit as horizontal series of crescent-in-crescent forms, in layers about one-fourth inch in thickness, extending horizontally many feet and made by different individuals. Most of the rock is composed of this structure. *Taonurus caudagalli* appears to have been formed by worms burrowing horizontally in a layer of mud, each burrow being about an eighth of an inch from the last. The burrow next to the one being formed collapsed and formed the crescents. After a fresh layer of mud one-fourth inch thick was laid down the new annual crop of worms worked over that layer, sometimes working over the top of the former layers. If the layers of silt represent annual layers, the 700 feet of Esopus grit, exclusive of the marine Schoharie, was deposited in about 34,000 years.

The characteristics and correlation of the faunas of the Pennsylvanian rocks of north Texas were then described by the author; discussion by E. O. Ulrich.

PENNSYLVANIAN FAUNAS OF NORTH TEXAS AND THEIR CORRELATION

BY RAYMOND C. MOORE

(Abstract)

Recent studies based on large collections of invertebrate fossils from the Pennsylvanian formations of north-central Texas indicate that three main faunal groups may be recognized: (1) that from the Bend, (2) that from the Strawn, Canyon, and lower Cisco, and (3) that from the middle and upper Cisco. While these are broadly related, there are distinguishing features which readily differentiate them. As similar faunal groups may be observed in the Pennsylvanian rocks of neighboring areas, there is furnished a fairly satisfactory basis for paleontologic correlation. However, the Pennsylvanian rocks of the Midcontinent region do not appear to be divisible on the basis of faunal distinctions into very minute, widely traceable units.

The Bend fauna, found in the strata of the Marble Falls limestone and Smithwick shale, is marked chiefly by an element which is suggestive of the

Mississippian, by the absence of many of the commonest fossils of the later Pennsylvanian, and by the presence of a considerable number of species which are restricted to this fauna. It closely resembles the fauna of the Wapanucka limestone of southern Oklahoma and that of the Morrow group in northeastern Oklahoma and northern Arkansas. It is the oldest known marine Pennsylvanian fauna in North America.

The second main faunal group is found in the rocks of the Strawn, Canyon, and lower Cisco. It contains a large assemblage of mollusks, among which are many of the most characteristic and widely distributed species of the period. Because of its very typical development and remarkably perfect preservation in the Wewoka formation of southern Oklahoma, where it has been described excellently by Dr. George H. Girty, this associated group of invertebrates may conveniently be designated as the Wewoka fauna. The composition of the fauna found in the Mineral Wells (upper Strawn) formation in north Texas is almost the same as that of the type Wewoka fauna. The Canyon formations, which are dominantly calcareous, contain a modification of the Wewoka fauna which is apparently a normal consequent of the clearer waters of this time. In the lower Cisco a recurrence of the typical Wewoka assemblage, with its numerous molluscan species, is seen in the remarkably fossiliferous shales of the upper part of the Graham formation. While this fauna contains a number of species which are restricted to Texas, a very large proportion is identical with the southern Oklahoma species. The stratigraphic divisions in Oklahoma which are faunally equivalent to the formations designated in Texas include most or all of the strata from the Atoka to Holdenville, in the Colgate region, and beds below the Ocheolata, in northeastern Oklahoma. In Kansas, Missouri, and States to the north, the faunal group regarded as equivalent to that described in Texas does not range above the Kansas City formation.

The fossils from the remaining portion of the Texas Pennsylvanian comprise a faunal group which is distinctive of the closing epoch in the period. It lacks an important element of the Wewoka fauna and is characterized by the appearance of several new species which are abundant and widely distributed in the rocks of the upper Pennsylvanian, some of them living on into the Lower Permian. The middle and upper Cisco which contains this fauna may be correlated closely with the Lansing to Wabaunsee formations of Kansas and their equivalents in adjoining States.

The lines of division between these main faunal groups appear to coincide with important interruptions in the deposition of sediments in the Pennsylvanian seas of the Midcontinent region and reflect broadly the physical history of the period. There is a considerable stratigraphic break between the Bend and succeeding deposits. The uplift of the Arbuckle Mountains and the spreading of much clastic debris across northern Texas and Oklahoma is associated with the change in the invertebrate faunas which is observed in the later Pennsylvanian.

The author of the following paper presented interesting observations upon the matter of attachment of the Paleozoic cup corals. Discussion by Messrs. Ulrich, Chadwick, and Bassler.

UNATTACHED SIMPLE PALEOZOIC CORALS

BY AUGUST F. FOERSTE

(Abstract)

Most simple *Tetracoralla* show no attachment areas. In many species only occasional specimens show attachment areas. Most attachment areas are too small to have supported the corallum except during its immature stages of growth. Mature coralla of most species were free. A few species with flattened sides apparently were adapted for drifting along the bottom of the sea with changing currents. Some of these were provided with opercula. Other forms may have lived with their apical ends more or less buried in mud or sand. Some of the radicleform offshoots from the epitheca may have served to anchor the specimens in loose mud or sand. Species represented only by attached specimens have relatively large attachment areas.

The paleontology and paleogeographic significance of an isolated outcrop of Devonian limestone 60 miles south of Quebec formed the subject of the next paper, presented by the author.

DEVONIAN LIMESTONE AT SAINT GEORGE, QUEBEC

BY THOMAS H. CLARK

(Abstract)

On the Chaudière River, about 60 miles southeast of Quebec, there is a small outcrop of Onondaga limestone with an abundant coral fauna. This limestone has been mentioned in geological literature but twice: first, by Logan, in 1863, and again, by Ells, in 1888. In company with Dr. P. E. Raymond, the writer visited this outcrop last summer and collected fossils from it. These are described and their significance with respect to the paleogeography of Onondaga time is discussed.

Stratigraphic results in the Paleozoic rocks of China obtained by Dr. A. W. Grabau, paleontologist of the Chinese Geological Survey, were given in the final two papers of the morning session, read by the Secretary in the absence of the author.

AGE OF THE COAL BEDS OF THE KAIPING COAL BASIN, IN NORTHEASTERN CHINA

BY A. W. GRABAU

(Abstract)

In the Kaiping coal basin of eastern Chihli Province, north China, thirteen coal seams (bituminous) are recognized. The lowest of these (number 13) is 35 centimeters in thickness, and its roof is formed by an impure limestone with crinoidal fragments, 30 centimeters thick, above which lies a massive argillite, often pyritiferous and containing a marine fauna of Lower

Permian affinities. Seventeen species have so far been differentiated, the best preserved and specifically determinable ones being of types elsewhere found in the Lower Permian of China. In shales above this horizon, but not accurately located (probably from seam 12 or higher), a fairly perfect specimen and several fragments of *Eurypterus* (*E. chinensis*) have been found. The flora from the several seams worked is a mixture of Stephanian and younger types, many Permian elements being present. The conclusion from the evidence so far obtained is that the coals are not older than Lower Permian. About 35 meters below seam number 13 is a very fossiliferous limestone (Tangshan limestone), generally less than a meter in thickness and containing numerous specimens of *Spirifer bisulcatus* Sowerby, *Lithostroton kaipingense*, and other fossils, identical with or allied to Viséan species of western Europe. This is, therefore, believed to represent a Dinantian (Mississippian) horizon. It is possible, but doubtful, that part of the intervening 35 meters may represent Moscovian or Uralian horizons, but so far no satisfactory paleontological evidence has been obtained.

The Tangshan limestone lies about 85 meters above the top of the Machiakou, or Actinoceras, limestone of Black River age. The intervening beds are red shales, fireclays, shales, and sandstones of Mississippian age. There is no Silurian or Devonian in north China.

ORDOVICIAN FORMATIONS OF NORTH CHINA

BY A. W. GRABAU

(Abstract)

The Ordovician is represented in north China by at least 800 meters of somewhat dolomitic limestones, with, locally, some intercalated shales. In the Kaiping coal basin of eastern Chihli Province the Ordovician rests disconformably on an erosion surface of highest Cambrian, beginning with a basal conglomerate, the pebbles of which are formed from the underlying Cambrian calciluytes. These lowest Ordovician beds (Yehli limestone) have so far yielded only two species of *Succoceras*. Eight hundred meters higher the limestones (*Actinoceras* or Machiakou limestones) contain a fairly rich fauna which shows the closest affinity with the Black River fauna of North America. Cephalopods and gastropods predominate. There are seven species of *Actinoceras* and eight species of *Lophospira*, besides others. The most remarkable feature of this fauna is its almost complete distinctness from the fauna of equivalent age found in south China, the two having scarcely a species in common. The Ordovician fauna from south China has European affinities, while that of north China is of the North American type.

Fifty miles north of the Kaiping basin, near the Manchurian border, a well marked Lower Ordovician fauna has been discovered by Dr. F. F. Mathieu, of the Kailan Mining Administration. This ranges through about 500 meters of rocks (mostly calcareous) and shows a remarkable affinity to the Beekmantown fauna of the Champlain region. It contains *Ophileta*, *Piloceras*, *Camero-ceras*, *Protocamero-ceras*, and the new holochoanitic cephalopod, *Chihlioceras*, representing a new family, the *Chihlioceratidae*. It also contains *Archæocyathus* of the same type as that found on the Mingan Islands, and, like that,

referable to the genus *Archæoscyphia* Hinde. The base of the series is not exposed, and it is disconformably succeeded by Coal Measures strata, the Machiakou or Actinoceras limestone being absent here. Three horizons are recognizable in this lower series, but their relation to the Yehli limestone is not yet clear. So far, there have been recognized in the Ordovician rocks of north China 31 genera and 58 species, 45 of these being specifically identified. All except five of these are new. Three new genera and one new family have been obtained.

The meeting then adjourned for luncheon.

PRESIDENTIAL ADDRESS

At 2.30 the Society met to hear the address of the retiring President of the Paleontological Society, entitled

SOME PROBLEMS CONNECTED WITH THE DAKOTA SANDSTONE

PRESIDENTIAL ADDRESS BY T. W. STANTON

The reading of papers before the Society in general session was then resumed, the first of the afternoon session being an account of the supplementary work upon the bibliographic catalogue of North American fossil vertebrates, including its plan, stage of completion, and prospect of its publication.

SUPPLEMENT TO THE BIBLIOGRAPHY AND CATALOGUE OF THE FOSSIL VERTEBRATES OF NORTH AMERICA

BY O. P. HAY

In the discussion which followed this paper it was voted unanimously by the members that representation be made to the Director of the U. S. Geological Survey to the effect that it was the hope of the Paleontological Society that Dr. Hay's catalogue be published as speedily as practicable.

Following this discussion the members interested in vertebrate paleontology retired to an adjoining room to meet in special session for the consideration of their more technical papers.

In the general session papers upon paleobotanical subjects were then read. The first two, bearing upon Cenozoic floras, were combined by the author, who gave an idea of the paleobotanic work carried on by him under the auspices of the Carnegie Institution.

FLORA OF THE PAYETTE FORMATION

BY RALPH W. CHANEY

(Abstract)

The flora of the Payette formation was originally considered to be of Miocene age, but in recent years it has been referred to the Upper Eocene because

of the presence in it of several Upper Clarno species. Collections during the past season have increased the number of species known from the flora and have shown a dominance of Miocene species which occur in the Mascall of Oregon. The occurrence of several Eocene species suggests that the Payette is somewhat older than the Mascall. It differs from the latter in having abundant sycamores, poplars, and other lowland types, indicating a habitat somewhat different from that in which the Mascall sediments were laid down.

FLORA OF THE RANCHO LA BREA

BY RALPH W. CHANEY

(Abstract)

The abundance of vertebrate remains from the Rancho La Brea deposits of southern California has emphasized the paucity of the fossil plants. The only well defined leaves which have been secured are those of an oak much like the living *Quercus agrifolia*; a few acorns resembling those of the same species have also been obtained. Cones of the knob-cone pine, *Pinus attenuata*, and of the Monterey cypress, *Cupressus macrocarpa*, are present in small numbers, and there is an abundance of wood which has been referred to *Cupressus*.

During the past summer a considerable amount of tar was carefully examined, but, aside from wood, a few undetermined seeds and stems resembling those of aquatic plants were the only materials collected. Further search may uncover situations where plants accumulated in abundance, but, on the basis of the material at hand, it appears that conditions did not favor the accumulation of plants. A possible explanation for these unfavorable conditions may be that the level topography did not permit much transportation of leaves and fruits, and that an arid or semiarid climate restricted the number of arborescent types much as it does today. The habitat indications of the known flora are quite consistent with this explanation.

The next paper, presented by the author and illustrated by many instructive lantern slides, was of special interest on account of its wide scope and general subject-matter.

PINES OF THE MESOZOIC AND THEIR RELATIONSHIP TO OLDER AND MORE
• MODERN TYPES

BY EDWARD C. JEFFREY

(Abstract)

The author has had the opportunity of studying recently many hundreds of specimens of Cretaceous representatives of pines and allied forms. It is clear from such studies that there were interesting types present at the epoch transitional between our modern pines and still more ancient types. It is a well established fact that existing pines are characterized by a definite and small number of needles in each cluster or short shoot. In the Cretaceous there were types with many needles on a short shoot. Further in the midst of the needles was a cluster of rudimentary leaves indicating a less degree of

specialization than in the modern species, where only the visible leaves of the fascicle are present and in limited number. In addition to these transitional forms, which represent both the hard and soft pines of the present epoch, there were other forms more nearly resembling our existing pines in having a definite limited number of fascicular leaves, namely, from two to five, but clearly contrasted to living pines in the fact that they possessed rudimentary leaves in the midst of the fascicular leaves. A third variant was represented by the genus *Prepinus*, in which the leaves are not only numerous in a fascicle with a leafy central growing region, but also characterized in contrast to the foliar organs of all other living gymnosperms by the presence of centripetal or cryptogamic wood. In this respect, as in many other, they present a striking resemblance to the leaves of the *Cordaitales*. The bearing of these facts on the conventional view that the Araucarian conifers are the oldest is discussed.

New facts on the structure of the hypoparian trilobites were described in the next paper, which was illustrated with lantern slides; remarks by Dr. Raymond.

ORDOVICIAN "HYPOPARIAN" GENERA OF TRILOBITES

BY E. O. ULRICH

(Abstract)

The author discussed the character, interrelations, stratigraphic position, and geologic distribution of the Agnostidæ, Trinucleidæ, Harpedidæ, and Ampyxidæ found in Ordovician formations in America. Most of these trilobites were shown to have originated in the North Atlantic realm, from which they invaded the Appalachian Valley troughs. Only *Cryptolithus* seems to have had a more southern origin, most of its species having invaded the interior continental seas by way of the Mississippi embayment.

In general, the author definitely disapproved the prevailing view that the marginal suture in the Trinucleidæ and Harpedidæ corresponds to the facial suture. He inclined instead to the opposing view, that the facial suture in these trilobites ran as in the Oplithoparia and became closed by fusion early in the life of individuals. He held that the marginal suture became a necessary convenience in moulting and possible through lateral and then posterior extension of the epistoma. In other words, the marginal suture represents a continuance of the frontal suture of most Oplithoparia to the genal angles. He pointed out also that *Olenellus* has a ventral plate that is comparable to the ventral plate of the cephalon of *Harpes*. As is well known, the facial suture in *Olenellus* is quite as thoroughly fused as in *Harpes*. The author exhibited enlarged photographs of the latter indicating that this suture followed essentially the same Oplithoparian course in both of these genera. It was concluded, therefore, that the Order Hypoparia must either be abandoned or preferably redefined. The author also questioned the desirability of the family Endymionidæ, recently proposed by Raymond, and dissents from the prevailing practice of referring all Ordovician Harpedidæ except *Harpides* to *Eoharpes*. He prefers to return most of them to the genus *Harpes*.

The Ampyxidæ were discussed at length and the genera of the family re-

defined. *Raphiophorus* Angelin could not be separated satisfactorily from *Ampyx*, but *Lonchodomus* of the same authority proved easily and constantly distinguishable by differences in the facial suture and in the anterior margin of the cephalon.

A new genus, *Ampyzina*, is proposed for small Ampyridæ with small and very short rostral spine, obovate glabella, a small pair of isolated posterior lateral glabellar lobes, and four or five thoracic segments. The pygidium also differs from that of *Ampyx* and *Lonchodomus* in wanting the thick, beveled and striated posterior edge. In *Ampyx* the second and third pairs of lateral glabellar lobes often are rather well developed and partly separated from the middle lobe, but the posterior pair is seldom well defined and never isolated. Six species of the new genus are known, only one of which has been described and figured, and this without either a generic or specific name. The description and figures referred to were published in 1909, by R. R. Rowley, in "The Geology of Pike County," Missouri Bureau of Geology and Mines, second series, volume 8, page 60, plate 15, figures 12-14. The species is not uncommon in the basal part of the Maquoketa shale west of Louisiana, Missouri, and along the Mississippi bank two or three miles above Thebes, Illinois. I propose now to call it *Ampyzina bassleri* n. sp., and to designate it provisionally as the genotype of *Ampyzina*. The other species are all older—Lower Trenton and Upper Chazyan. One occurs with *Cryptolithus* n. sp. in the Viola limestone in Oklahoma, another in the basal 10 feet of the Martinsburg shale at Chambersburg, Pennsylvania, and three others in subcrystalline limestone lying just beneath the Athens shale, near Blacksburg and Saltville, Virginia, and near Albany and other places in Tennessee. One of the last three may be the same as *Raphiophorus powelli* Raymond.

The genera mainly concerned in these studies are *Agnostus*, *Ampyx*, *Lonchodomus*, *Ampyzina*, *Trinucleus*, *Cryptolithus*, *Harpe*, and *Eoharpe*?. The species and varieties of each have been most critically determined, and as thus conceived have proved themselves of great value as guide fossils in correlating the Chazyan and Mohawkian formations in the Appalachian region. Publication of the species will proceed as opportunities offer.

Under the following title the author brought out the fact that the foraminifera hitherto supposed to be extremely variable are in reality not so at all, for a close study of both fossil and recent species has shown much of this so-called variation to be due either to unrecognized stages in development, the peculiar alternation of generations developed in this group, or to the lack of close discrimination of specific characters.

LIMITS OF VARIATIONS IN FORAMINIFERA

BY J. A. CUSHMAN

An interesting paper describing the paleontological work being done in the Gulf Coast oil fields by the oil companies located at Houston, Texas, was then presented by Miss Esther E. Richards for the author.

RECENT GEOLOGICAL WORK IN GULF COAST OIL FIELDS

BY E. T. DUMBLE

The concluding paper of the afternoon dealt with the stratigraphy of central Tennessee, especially with reference to the significance of the distribution of the various formations. Illustrated by lantern slides; discussed by Messrs. Raymond, Ulrich, and Reeds.

MOHAWKIAN AND CINCINNATIAN ROCKS OF CENTRAL TENNESSEE

BY R. S. BASSLER

(Abstract)

The Carters, Lowville, and Kimmswick formations, of Black River age; the Curdsville, Hermitage, Bigby, Cannon, and Catheys formations, of Mohawkian age, and the Leipers formation, of Cincinnati age, all rather easily distinguished faunally and lithologically, prove in the course of extensive mapping to be developed quite unequally on different sides of the Nashville dome. For example, the Carters limestone is thickest on the western side, while the overlying Lowville limestone is thickest on the eastern side; the Kimmswick limestone outcrops only on the southern flank, while the next younger formation, the Curdsville limestone, is found only on the northern side. The chief reason for these differences is believed to be due to oscillation, and the great development of phosphatic rock in the Hermitage, Bigby, Catheys, and Leipers formation is considered as likewise connected with the same phenomenon.

At 5.30 p. m. the Society adjourned until the next day.

Thursday evening at 7 o'clock the annual dinner of the Geological Society of America and affiliated societies was held at College Hall of Amherst College, in which our members participated.

SESSION OF FRIDAY, DECEMBER 30

President Stanton called the general section of the Society to order Friday morning at 9.30, while the vertebrate paleontologists continued in special session.

REPORT OF THE AUDITING COMMITTEE

The chairman of the Auditing Committee read a statement attesting to the correctness of the Treasurer's accounts, and it was then voted that the report be accepted.

PRESENTATION OF PAPERS

The first paper on the program comprised new evidence on the Chester problem, presented by the author, who discussed critical sections in the area under discussion to prove his points.

FEW MORE FACTS BEARING ON THE CORRELATION OF THE CHESTER FORMATIONS

BY E. O. ULRICH

A paleobotanical subject followed, illustrated by lantern slides, which showed the clearness and detail that can be obtained in thin sections of fossil plants.

OCCURRENCE OF THE PARICHNOS OF BERTRAND IN CERTAIN GYMNASPERMS

BY E. C. JEFFREY

(Abstract)

The structure of Parichnos is well known for *Lepidodendron* and *Sigillaria*. The author has found similar structures in certain living gymnosperms. They accompany the leaf-traces from the surface of the central cylinder out to the base of the leaf, where they end in the spongy central green substance of the leaf. Sometimes the Parichnos of gymnosperms appear as canals and sometimes merely as strands of richly aëriferous parenchyma. Their significance from the physiological and morphological standpoints is discussed, as well as the possibility of their indicating relationship between the gymnosperms in which they are found and the Lepidophyta.

The final paper presented at the meeting was an interesting discussion given by the author.

AGE AND DEVELOPMENT OF RED BEDS AND THE TERRESTRIAL VERTEBRATES IN THE APPALACHIAN AND THE KANSAS-TEXAS REGION

BY J. W. BEEDE

(Abstract)

1. Review of postulate regarding uneven development of Red Beds and Permian terrestrial vertebrates of the Appalachian and Western Plains provinces of the United States.
2. Review of development of marine invertebrates and plants in these regions during Pennsylvanian and Permian times, which show relatively little progress during upper Pennsylvanian time and a marked quickening of the evolutionary processes at the beginning of Permian time.
3. Review of the history of the vertebrate life during this time, and the conclusion that it, too, has, so far as known, relatively little expansion during the upper Pennsylvanian, with marked expansion, specialization, and change of fundamental aspect beginning at the base of the Permian and continuing at least until the close of the Clear Fork epoch of the Permian.
4. Demonstration of the accumulation of Red Beds deposits earlier in the Pennsylvanian period in the Wichita Mountain region than any now preserved in the rocks of the Pennsylvanian period of Ohio, West Virginia, and Pennsylvania.

In the absence of the authors, the following papers were read by title:

METHODS OF STUDYING AMMONITES

BY MARJORIE O'CONNELL

LUNAR PETREFACTIONS

BY F. W. SARDESON

At noon the Society adjourned.

SECTION OF VERTEBRATE PALEONTOLOGY

Members interested in vertebrate paleontology formed a separate section Thursday, at 3.30 p. m., with Dr. W. J. Sinclair presiding.

PRESENTATION OF PAPERS

In the first paper of the session Dr. Troxell summarized briefly the few discoveries of dinosaurs, aside from footprints, that had been made in the Newark sandstones of the Connecticut Valley, with additional data of the circumstances of each discovery secured by him in field-work last summer, and showed certain problematic fossils which he had found.

FOSSILS OF THE CONNECTICUT VALLEY

BY EDWARD L. TROXELL

(Abstract)

About a dozen specimens of reptiles have been found in the Newark series of New England, showing that they are remarkably rare as compared to the number and variety of the footprints; none of those known are large enough to have made certain of the footprints, which measure 20 inches in length.

A search during the summer resulted in the finding of one or more undoubted bone fragments of the smaller *Anchisaurus*, and other fragments which are doubtfully referred to the larger reptiles. Other interesting material was found: silicified and carbonized wood, *Unio* shells of a new variety, footprints in a new locality, and fish from the well known black shales.

HYRACODONS FROM THE BIG BADLANDS OF SOUTH DAKOTA

BY W. J. SINCLAIR

(Abstract)

Comparison of a large series of dentitions from the various levels of the White River enabled the author to determine certain characters, especially in the premolars, as constant and valid specific distinctions. Size was found to

be extremely variable and the species do not appear to be good horizon-markers.

A discussion followed concerning the standards of species distinction and methods of description among fossil mammals, in which the author, Dr. Troxell, Dr. Thorpe, Professor Lull, Dr. W. D. Matthew, and Dr. O. P. Hay participated.

In the next paper the author proposed to transfer the Harrison and Rosebud group of formations of the Great Plains to the Oligocene, correlating them with the John Day formation of Oregon, and included in the Miocene the Clarendon, Loup Fork, and Santa Fé marls, referred to the Pliocene by previous writers. The paper was discussed by Dr. Matthew, who dissented from the changes proposed.

RELATIONSHIP OF THE GREAT BASIN AND GREAT PLAINS FAUNA

BY EDWARD L. TROXELL

(Abstract)

The study of the vertebrate fossils in the Marsh Collection from these two widely separated regions suggests a new arrangement of the stratigraphic column, which is here presented, with the conclusion that the Arikaree is not Lower Miocene, but Upper Oligocene, and that the dividing line between the latter and the true Miocene should be above the Rosebud and Harrison formations.

Great Plains		Great Basin	
Lower Miocene	} Pawnee Creek.	Mascall.	
		Columbia lavas.	
Unconformity.		Upper Oligocene	
Upper Oligocene	{ Rosebud-Harrison. Monroe Creek-Gering	Upper John Day.	
(Arikaree)		Middle John Day.	

Not only is there a great similarity between the John Day formation of Oregon and the Arikaree of Dakota and Nebraska, but these strata seem to be synchronous with the Oligocene of the Old World.

The following important groups of animals reach extinction in the Arikaree: The hypothetical Upper Oligocene entelodont (*Dinohyus*), *Steneosaber*, *Dicera-therium* (*Carnopus*, *Metacarnopus*, *Menoceras*), *Eporeodon-Mesoreodon*, *Leptauchenia*, *Mesohippus-Miohippus*, *Protoceras-Syndyoceras*, and *Hypisodus*, while with the true Miocene we have the introduction of the proboscideans, teleocerine rhinoceroses, and horned artiodactyls.

The meeting was then adjourned.

The session of the Vertebrate Section was resumed at 9:30 a. m., Friday, December 30, Dr. Sinclair in the chair. The following papers were presented:

RESTORATION OF BLASTOMERYX

BY R. S. LULL

The author showed photographs of a mounted skeleton of *Blastomeryx* in the Peabody Museum, with the form of the body restored on one side. It is based on two individuals from the later Miocene. The species shows well developed lanial tusks and a rudimentary horn over the orbit, unlike the Lower Miocene species described by Matthew.

Dr. Matthew remarked that the *Blastomeryx* described by Scott in 1891, also probably from the Upper Miocene, had a rudimentary horn.

SUPPOSED LABYRINTHODONT FOOTPRINTS FROM THE MARYLAND CARBONIFEROUS

BY R. S. LULL

(Abstract)

The series of footprints described were exposed on a considerable surface of shale. They were not as clear in detail as might be desired, but represented a large animal, comparable in size to *Paricosaurus*.

A large limb-bone from the Pennsylvanian of West Virginia, submitted some years ago to the Society by Dr. I. C. White, was thought to represent a type that might be responsible for such footprints as the author described. Dr. White's specimen was considered as pretty certainly a natural cast of a limb-bone, although some authorities had questioned it.

Discussed by Dr. Matthew and Dr. Wieland.

UPPER PAWNEE CREEK BEDS

BY F. B. LOOMIS

(Abstract)

During field-work last summer the author had verified the existence of a distinct upper fossil zone overlying the true Pawnee Creek beds in Weld County, Colorado, as suspected by Matthew and Osborn from faunal studies. The fauna was of Lower Pliocene age, but with a considerable admixture of redeposited fossils from the true Pawnee Creek beds.

LOWER MIOCENE AT VAN TASSEL, WYOMING

BY F. B. LOOMIS

(Abstract)

A rich fossiliferous pocket in the Lower Harrison beds close to the village of Van Tassel had been profitably exploited by the author and was well worth further work. The fauna contains elements which are found at Agate, Nebraska, but differs in being dominantly a deposit of Oreodonts. The collection from this region is described, there being several new species, and a horse, *Parahippus tyleri*, which gives a much more complete idea of this formerly little known type. The fauna fills in much that is lacking at Agate and gives with the Agate forms a much more balanced idea of the life of the time.

In the next paper, read by Dr. Matthew, the author describes footprints of which plaster casts were exhibited.

HUGE AMPHIBIAN FROM THE UPPER COAL MEASURES OF KANSAS

BY H. T. MARTIN

(Abstract)

A huge amphibian is indicated in a series of footprints recently discovered in the sandstone of the Upper Coal Measures of Kansas. The impressions, measuring some 7 inches in length and 6 inches in breadth, extend for a distance of 25 feet with slight interruptions, along a sandstone ledge, which is regarded as a phase of the Weston shales, lying immediately below the Kickapoo (Iatan) limestone, exposed on the banks of the Wakarusa Creek, near Dightmans Crossing, some 5 miles southeast of Lawrence, Kansas.

Some of the impressions are very well preserved, and indicate four toes on the front feet and five on the hind feet, for which reason I think an amphibian is indicated. Large amphibians are known from the Kansas Coal Measures by the footprints described by Mudge and Marsh from Osage County and by skeletal remains described by Moodle from Washington County. A much larger type of vertebrate is indicated by the present footprints, however; in fact, we may say that these footprints represent the largest land vertebrates so far recorded from the pre-Triassic rocks. The majority of Coal Measures amphibians are extremely small, measuring only a few inches in length; but the animal which made these tracks must have been from 15 to 20 feet in length and is comparable in size to *Mastodonsaurus* of the European Triassic.

In the following paper the primitive characters of the Merycoidodontidae were listed in some detail, showing a considerable approach to the Creodonta and primitive Carnivora as compared with the higher artiodactyls. Dr. Matthew remarked on the desirability of instituting more exact comparisons with the Eocene Artiodactyla as known principally from the European formations.

*PRIMITIVE AND CARNIVORE-LIKE CHARACTERS OF THE
MERYCROIDODONTIDÆ*

BY MALCOLM RUTHERFORD THORPE

(Abstract)

The type of this great group was described by Dr. Joseph Leidy in April, 1848. Subsequently he pointed out resemblances between *Merycoidodon* and the peccary, the camel, and the wolf, and characterized this family as "ruminating hogs," a name which has since clung to the whole group.

There are some twenty-six genera and subgenera in the Merycoidodont family, with about fourteen in the pre-Miocene, and it is the latter which are herein considered. The Eocene and Oligocene species show a close similarity in structure. The late Oligocene and early Miocene was a very important

time in the racial history of the Oreodont family, and from this period they began to diverge into various terminal lines of development, leading finally to complete extinction.

In summary of the various supposedly primitive and carnivoroid characters, we find twenty-six major primitive and twenty-four carnivoroid, of which approximately one-half are common to both. These may be listed as follows:

(1) Characters which are both primitive and carnivoroid: (*a*) Dolichocephaly, (*b*) well marked postorbital constriction, (*c*) prominent sagittal crest, (*d*) high overhanging occiput, (*e*) relatively large head, (*f*) more or less elongate face, (*g*) very large temporal fossa, (*h*) palate narrow and somewhat arched transversely, (*i*) presence of well developed canines, (*j*) long body and long tail, (*k*) short legs, and (*l*) dorso-lumbar vertebral formula of 19-20.

(2) Characters which are primitive: (*a*) Stout, heavy zygomata, (*b*) long, robust, downwardly-projecting paroccipitals, (*c*) relatively large lacrymal bone, (*d*) well developed milk dentition, (*e*) complete dentition of forty-four teeth, (*f*) probable omnivorous habit, (*g*) brachyodonty, (*h*) large spine on axis, (*i*) large size of lumbar compared with dorsals, (*j*) broad blade of scapula, (*k*) five digits in manus, (*l*) stout puboischiadic symphysis of pelvis, (*m*) relatively small pelvic outlet, and (*n*) absence of bullæ in the earlier forms.

(3) Characters which are carnivoroid: (*a*) Broad mandibular coronoid, (*b*) long mandibular symphysis, (*c*) incisors subtransverse, (*d*) relative positions of basiscranial foramina, (*e*) relatively large infra-orbital foramen, (*f*) tongue and groove articulation on lumbar zygapophyses, (*g*) spine of scapula dividing it into two subequal parts, (*h*) position of acromium and metacromium, (*i*) humerus and ulna, (*j*) metapodials long, slender, keeled (phalanges and ungues), (*k*) femur and tibia, (*l*) semi-digitigrade.

The author's use of the term primitive is only relative—that is, the characters which he considers generalized in this group are, in some instances, not so in other groups. Some of these also may be secondary developments, due to muscle responses or other causes, such as may have produced the heavy zygomata and robust paroccipitals and the possible omnivorous habit.

The carnivoroid characters may be secondary, as Doctor Matthew considers to be the case in *Agriocharus*, or they may be primary, which does not seem to be an unreasonable supposition.

The author of the next paper showed lantern slides of a mounted skeleton and restoration in the Museum of Yale University. Although listed generally as from Oregon, this species is really from the Upper Oligocene of Nebraska.

RESTORATION OF *EPOREODON SOCIALIS*, MARSH

BY MALCOLM RUTHERFORD THORPE

(Abstract)

One of the two cotype skeletons of this genus and species has just been mounted at the Peabody Museum of Yale University. After the skeleton was

erected the restoration of the flesh was made by Professor Lull, based on a most careful study of the musculature of recent animals. The muscles were built up over the actual bones and every attention was paid to the rugose bone surfaces for muscle attachment, which clearly gave evidence of the size and power of each muscle. The result is a rather doglike animal and gives one an entirely different conception of the appearance and character of these animals than that conveyed by Leidy's phrase, "ruminating hogs."

Slides of this mount were shown, as well as those of six other mounts of different genera and species in different museums. It appears to the writer that in the majority of the mounts the attitude seems a little too piglike, and that the probable semi-digitigrade gait is not sufficiently emphasized. Some of these mounts appear to have the head somewhat more elevated than in the specimen at Yale.

The Yale specimen is now in process of casting, in order to insure greater permanency of the flesh restoration. The final result will be the equivalent of a panel mount, but with the plaster reconstruction in place of the usual panel.

NEW LIGHT ON THE PHYLOGENY OF THE CANIDÆ

BY W. D. MATTHEW

A series of skulls of Canidæ from the Lower Snake Creek Upper Miocene of Nebraska was obtained last summer by the American Museum Expedition. These show the intermediate stages between the Canidæ of the Oligocene and the Pleistocene and recent members of the family. Huxley's arrangement of the family into alopecoid and thooid divisions is wholly rejected, the modern Canidæ being divided into two groups, one including *Cyon*, *Icticyon*, and *Lycaon*, the other all the remaining genera. These two groups are derived through two parallel series of ancestral stages from the Eocene *Cynodictis*. The extinct group of Amphicyonine dogs is derivable from the Lower Oligocene *Dufhanus* through several intermediate stages, and the Middle Eocene genus, *Miacis*, is probably the common ancestor of the family. The various stages are represented by a series of skulls from the different Tertiary horizons.

TOOTH OF ALMOST HUMAN TYPE FROM THE LOWER PLIOCENE SNAKE CREEK BEDS OF WESTERN NEBRASKA

BY HAROLD J. COOK

Read by Dr. W. J. Sinclair.

The only example of the Simocyonid group of Canidæ in North America formed the subject of the next paper.

AREOCYON, A PROBABLE OLD WORLD MIGRANT

BY MALCOLM RUTHERFORD THORPE

(Abstract)

In the American Journal of Science for June, 1921, I described the lower jaw of a carnivore collected in the Rattlesnake formation of Oregon in 1874

through the efforts of Prof. O. C. Marsh. For this carnivore I proposed the name *Pliocyon marshi*. Subsequently, in the same Journal, for January, 1922, I substituted the name *Aræocyon*.

The presence of this lower jaw in Middle Pliocene deposits of the New World is exceedingly interesting, as it is the only specimen of its kind described or reported from the ancient fauna of North America.

Structurally, *Aræocyon* is remarkably close to *Simocyon primigenius* Roth and Wagner from the Pikermi deposits (Upper Miocene) of Greece. The faunal affinities of the Pikermi genera are with those of Africa rather than with Europe, but we also find a similar faunal phase eastward in Samos and at Maragha, Persia, while in general the fauna of the latter approaches very closely to that of the Pliocene of the Siwaliks in southern Asia and of China.

In the Pliocene, Asia and North America were connected by land and intercontinental faunal migrations took place. Owing to the general eastward trend of the fauna, as mentioned above, it is not unreasonable to suppose that the carnivores also followed the other groups, and that there might have been a concentration of carnivore types in the constricted region of this "game trail" at what is now known as Bering Strait. During the gradually increasing cooling of the northern region in the Pliocene, it became necessary for the fauna in the main to migrate southward—a movement which, if this theory be true, was carried on by *Aræocyon* as far south as Oregon. Therefore my view at present, and Professor Lull is in agreement with it, is that some of the members of the genus *Simocyon* migrated from southern Europe through Asia and into North America during the latter part of the Upper Miocene and the first half of the Pliocene, and that the time involved was sufficiently long for the former representatives of *Simocyon* to develop into *Aræocyon*.

On the other hand, if *Aræocyon* is an autochthonous form, then we must place it in the pseudo-canoid phylum, namely, those with the trenchant-heeled inferior molars, wherein we find *Daphænus*, *Temnocyon*, *Enhydroyon*, *Cyon*, *Icticyon*, and *Lycaon*.

If this lower jaw on which *Aræocyon* is established had been collected in the Pliocene of Europe, I should have no hesitation in referring it to the genus *Simocyon* or possibly to a subgenus under it, and if *Aræocyon* should finally prove to be autochthonous, then it will be one of the most remarkable cases of convergence on record.

A summary of the results of the American Museum Expedition last summer in the Snake Creek fossil quarries, Miocene and Pliocene of western Nebraska, was given under the following title:

SNAKE CREEK FAUNA

BY W. D. MATTHEW

There was then presented by title

PHYLLOGENY AND NOMENCLATURE OF THE PROBOSCIDEA

BY HENRY FAIRFIELD OSBORN

The session was then adjourned.

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DERBY, ORVILLE A., died November 27, 1915.
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PROSSER, C. S., died September 11, 1916.
SEELY, HENRY M., died May 4, 1917.
WARING, CLARENCE A., died November 4, 1918.
WILLIAMS, HENRY S., died July 31, 1918.
WILLISTON, SAMUEL W., died August 30, 1918.

Proceedings of the Paleontological Society

PROCEEDINGS OF THE FOURTEENTH ANNUAL MEETING
OF THE PALEONTOLOGICAL SOCIETY, HELD AT ANN
ARBOR, MICHIGAN, DECEMBER 28-30, 1922.

R. S. BASSLER, SECRETARY

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VOL. 34, PP. 121-142

MARCH 30, 1923

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SESSION OF THURSDAY, DECEMBER 28

The first session of the Society, announced for 2 p. m. Thursday, December 28, was postponed until Friday morning, so that the members could attend the symposium on "The Structure and History of Mountains and the Causes of their Development," commencing at that time in the meeting of the Geological Society of America. The closing hour of the morning was devoted to the address of Charles Schuchert, Fellow of the Paleontological Society and retiring President of the Geological Society of America. Professor Schuchert's address, which was introductory to the symposium, was entitled "Sites and nature of the North American geosynclines."

Thursday evening the members met with the Geological Society of

America and other affiliated societies in the complimentary smoker tendered by the University of Michigan at the Michigan Union.

SESSION OF FRIDAY, DECEMBER 29

President Matthew called the Society to order in its fourteenth annual meeting, at 9.30 a. m., in the Science Building of the University of Michigan. After welcoming the members, the report of the Council was read.

REPORT OF THE COUNCIL

To the Paleontological Society, in fourteenth annual meeting assembled:

The Council has held its customary meetings just before and after the annual meeting of the Society and has transacted other business by correspondence. A résumé of the administration of the Society's business during the fourteenth year is given below.

SECRETARY'S REPORT

To the Council of the Paleontological Society:

The Secretary's report for the year ending December 27, 1922, is as follows:

Meetings.—The proceedings of the thirteenth annual meeting of the Paleontological Society, held at Amherst, Massachusetts, December 28-30, 1921, have been printed in volume 33, number 1, of the Bulletin of the Geological Society of America, pages 191-222.

The Council's proposed nominations for officers and the announcement that the fourteenth annual meeting would be held at Ann Arbor, Michigan, December 28-30, 1921, as the guest of the University of Michigan, was issued March 22, 1922.

Membership.—The Society has been fortunate in having no loss of membership during the year. Five new members have just been elected and eight additional nominations are awaiting consideration at the present meeting. This year two of our members have been elected to fellowship in the Geological Society of America and four Fellows of that Society have asked for election to our own. The result of these various changes leaves a total number of members at the end of 1922 of 228.

Publications.—In addition to the Proceedings, four papers by members have been published in the Bulletin of the Geological Society of America.

Respectfully submitted,

R. S. BASSLER,

Secretary.

WASHINGTON, D. C., December 26, 1922.

TREASURER'S REPORT

To the Council of the Paleontological Society:

The Treasurer begs to submit the following report of the finances of the Society for the fiscal year ending December 23, 1922:

RECEIPTS

Cash on hand December 24, 1921.....	\$672.27
Membership fees.....	297.30
Interest, Connecticut Savings Bank.....	24.46
	<hr/> \$994.03

EXPENDITURES

Secretary's office:	
Secretary's allowance.....	\$50.00
Clerical work.....	25.00
Office expenses.....	59.30
	<hr/> \$134.30
Treasurer's office:	
Treasurer's allowance.....	\$25.00
Postage	3.00
	<hr/> 28.00
Geological Society of America:	
Printing programs, etcetera.....	\$3.45
Reprints	26.06
	<hr/> 29.51
	<hr/> 191.81
Balance on hand December 23, 1922.....	\$802.22
	<hr/>
Net increase in funds.....	\$129.95
Outstanding dues (1921, 1; 1922, 11).....	36.00

Respectfully submitted,

RICHARD S. LULL,
Treasurer.

NEW HAVEN, CONNECTICUT, *December 23, 1922.*

APPOINTMENT OF AUDITING COMMITTEE

A committee consisting of W. H. Twenhofel and F. B. Loomis was then appointed by the President to audit the Treasurer's accounts.

ELECTION OF OFFICERS AND MEMBERS

President Matthew then announced the results of the ballots for the election of officers for 1923 and of new members.

OFFICERS FOR 1923

President:

T. WAYLAND VAUGHAN, Washington, D. C.

First Vice-President:

W. A. PARKS, Toronto, Ontario

Second Vice-President:

W. H. TWENHOFEL, Madison, Wis.

Third Vice-President:

O. P. HAY, Washington, D. C.

Secretary:

R. S. BASSLER, Washington, D. C.

Treasurer:

RICHARD S. LULL, New Haven Conn.

Editor:

WALTER GRANGER, New York City

NEW MEMBERS FOR 1923

JOSIAH BRIDGE, Missouri School of Mines and Metallurgy, Rolla, Missouri.

JENNIE DORIS DART, 114 High Street, New Haven, Connecticut.

GEORGE M. EHLERS, University of Michigan, Ann Arbor, Michigan.

HANDEL T. MARTIN, University of Kansas, Lawrence, Kansas.

GEORGE B. TWITCHELL, 845 Dayton Street, Cincinnati, Ohio.

The President then called for the following nominations to membership which had arrived too late for insertion on the printed ballot and which had received the approval of the Council:

HENRY G. CLINTON, Superintendent of Black Mammoth Consolidated Mining Company, Manhattan, Nevada. Student of invertebrate paleontology. Proposed by E. O. Ulrich and R. S. Bassler.

EDWARD J. FOYLES, American Museum of Natural History, New York City. Student of invertebrate paleontology. Proposed by Ralph W. Chaney and R. S. Bassler.

HEDWIG T. KNIKER, The Texas Company Building, Houston, Texas. M. A., University of Texas, 1917. Proposed by Julia A. Gardner and R. S. Bassler.

MRS. HELEN MORNINGSTAR LAMBORN, Department of Geology, Ohio State University. Ph. D. (1921), Bryn Mawr. Proposed by R. S. Lull and R. S. Bassler.

JOSEPH K. ROBERTS, Assistant Professor of Geology, Vanderbilt University, Nashville, Tennessee. Ph. D., Johns Hopkins University, 1922. Proposed by E. W. Berry and R. S. Bassler.

RICHARD W. SMITH, Assistant Geologist, State Geological Survey, Nashville, Tennessee. B. S., Massachusetts Institute of Technology, 1921. Proposed by E. O. Ulrich and R. S. Bassler.

WALTER C. TOEPELMAN, Assistant Professor of Geology, University of Colorado, Boulder, Colorado. A. B., University of Oklahoma, 1916. Proposed by Junius Henderson and R. S. Bassler.

PERCIVAL S. WARREN, University of Alberta, Edmonton, Alberta. B. A., University of Toronto, 1920. Proposed by W. A. Parks and R. S. Bassler.

After the qualifications for membership of each one of the above list had been presented to the Society, it was moved by Dr. Clarke and seconded by Professor Twenhofel that the By-Laws be suspended and that the Secretary be instructed to cast the vote of the Society for the election of these eight new nominations. Motion carried.

ELECTION OF REPRESENTATIVE ON NATIONAL RESEARCH COUNCIL

Dr. Matthew then announced that the election of a representative of the Society in the Division of Geology and Geography of the National Research Council was necessary, as Dr. Vaughan, having just completed three years of service in this position, was ineligible for reelection.

Upon vote by the Society, after motion by Professor Twenhofel, Dr. F. H. Knowlton was elected to this position.

NEW BUSINESS

The Secretary announced that J. E. Carman and John L. Tilton, both Fellows of the Geological Society of America, wished to be enrolled in the membership of the Paleontological Society, and that J. W. Gidley and Stanley Smith, just elected to fellowship in the former Society, should also be placed on our rolls. Upon motion, it was voted that the Society should add these four names to our membership.

Dr. John M. Clarke moved that, in view of the surplus in the funds of the Society, the Secretary's allowance be increased to \$100. Motion carried. There being no further business, the reading of papers was commenced in general session, with President Matthew in the chair.

PRESENTATION OF PAPERS

The first four papers of the program, all illustrated by lantern slides, were combined into a single presentation by the author. Discussion by Messrs. Parks, Loomis, Matthew, and Troxell followed.

THE BURTON DICTYOSPONGE

BY JOHN M. CLARKE

(Abstract)

This is a hexactinellid, or glass sponge, from a Chemung (Devonian) formation at Ripley, Chautauqua County, New York. The specimen described is of great size; represents, it is believed, the apertural portion of the individual, and, on the basis of other known specimens, it has been restored, the restoration and original specimen both being in the New York State Museum. The restoration gives a length of somewhat more than 10 feet. The sponge belongs to the genus *Ceratodictya* and is probably identical with the species of the Chemung formation, *C. carpenteriana* Hall and Clarke. The original specimen was found by Mrs. H. P. Burton in her 103d year.

RESTORATION OF THE COHOES MASTODON

BY JOHN M. CLARKE

(Abstract)

The Cohoes mastodon was found in a glacial pothole in the Mohawk River at Cohoes, New York, in 1865 and its skeleton is in the New York State Museum. A careful restoration of this has been made by the most careful and exact procedures and constitutes the only known attempt to represent the animal in its living state. The restoration was made by Noah T. Clarke and Charles P. Heidenrich.

PYORRHŒA IN THE COHOES MASTODON

BY JOHN M. CLARKE

(Abstract)

This skeleton has pathological dentition and erupted but one tooth on the left ramus of the mandible. This tooth has an abnormal insertion and a very imperfect opposition with the upper molars. As a result, the face of the animal is deformed and an osseous lump developed on the proximal surface of the mandible. An examination of the tooth and its socket by skillful dentists seems to have demonstrated the existence of long-continued pyorrhœal conditions, with attendant bone necrosis.

TEMPLE HILL MASTODON

BY JOHN M. CLARKE

(Abstract)

This skeleton was exhumed in 1921 from a truck garden near Temple Hill, about four miles west of Newburgh, Orange County, New York. Except for the Warren mastodon, the skeleton of which was found not far away, the new skeleton is the most complete known, the missing bones being largely a portion of the ribs and the upper surface of the cranium, which was destroyed by the

plow of the farmer. A notable feature of the skeleton is the evident incurvature and overlap of the tusks at their extremities, which are beveled, one above and one below, in such a manner as to demonstrate that the tusks formed an entire circle about the trunk.

Some of the results of the explorations of the American Museum of Natural History in China were presented by President Matthew in the following paper:

PLIOCENE MAMMALS OF SOUTHERN CHINA

BY W. D. MATTHEW AND WALTER GRANGER

(Abstract)

A large collection of skulls, jaws, and bones of fossil mammals was obtained by Mr. Granger in the winter of 1921-22 from a locality near Wan-hsien, in the province of Sze-chuan. The fauna is of late Pliocene or Pleistocene age, apparently a forest facies. Principal mammals are *Stegodon*, a rhinoceros near *R. indicus*, a giant tapir, a species of gaur (*Bibos*), several antelopes and large and small Cervidae, a pig, a tiger, *Hyana*, *Aeluropus*, *Helarctos*, *Cyon*, *Arctonyx*, *Viverra*, a large bamboo-rat, a rabbit, a large macaque, and a new primate, probably allied to the gibbon. A single molar represents the *Challiotheres*.

In view of the recent activity in work upon the Mississippian formations of the Mississippi Valley, the next paper presented by the author was of particular interest. Discussion by Messrs. Ulrich, Thomas, and Bassler.

*EARLY MISSISSIPPIAN FORMATIONS OF THE TYPE REGION ALONG
MISSISSIPPI RIVER, IN IOWA, ILLINOIS, AND MISSOURI*

BY RAYMOND C. MOORE

(Abstract)

Stratigraphic and faunal studies of the early Mississippian Kinderhook group along Mississippi River and in its vicinity, in southeastern Iowa, western Illinois, and northeastern Missouri, are the basis for a partial redefinition of the group and for the establishment of more definite correlation between exposures.

The carefully studied section at Burlington, Iowa, which is typical of deposits in a faunal province of northern affinities, is believed to include stratigraphic equivalents of the formations at Kinderhook, Illinois, and in Missouri, the latter representing lithologic and faunal developments which in the main are not observed to the north. It appears that the deposits of earliest Mississippian time in this region are marked by somewhat unusual local variations in the character of the sediments laid down and in the distribution of the invertebrate faunas. In the lowermost stratigraphic divisions which are here regarded as Mississippian there is a prominent faunal element suggestive of

the Upper Devonian, but there is a progressive and rapid increase in those forms which may be regarded as distinctively Mississippian. In general, the Kinderhook is not separated from the overlying Osage formations by an erosion interval, but the inauguration of a new stratigraphic division is indicated by a more or less marked change in lithology and, more importantly, by the introduction of faunas which are widely distributed and which in their cosmopolitan character contrast strongly with the very provincial Kinderhook faunal units.

Results of field-work in paleobotany and stratigraphy carried on during the summer of 1922 under the auspices of the Carnegie Institution were outlined by the author of the following paper:

PALEOBOTANICAL CONTRIBUTIONS TO THE STRATIGRAPHY OF CENTRAL OREGON

BY RALPH W. CHANEY

(Abstract)

The Crooked River occupies an area 30 to 50 miles south of the John Day Basin, in central Oregon. A comparison of the Crooked River section as exposed between Prineville and Paulina with that of the John Day Basin indicates that the sequence of the formations is practically identical. The Crooked River section shows several hundred feet of the Clarno formation with a characteristic Lower Clarno flora, and up to 4,000 feet of the John Day series, which carries near its base a flora similar to that of the Bridge Creek locality in the John Day Basin. The lavas overlying resemble the Columbia River lavas. A notable feature is the presence of dikes, which extend for over twenty miles and appear to connect with the lava flows. The formations overlying the basalt have yielded no fossils as yet, but they show a close lithologic similarity to the Mascall and Rattlesnake formations, which are the topmost members of the section in the John Day Basin to the north.

The flora of the John Day series includes over 25 species, most of which are present at the Bridge Creek locality of the John Day Basin. Live oaks, birch, poplar, elm, maple, sycamore, ironwood, and sequoia are among the more common forms. In the main these comprise a typical floodplain assemblage; the oaks and poplars suggest ridges on whose dry slopes such xerophytic types now live. A relatively high relief is also indicated by the local abundance of sequoia, suggesting that during the Oligocene, as today, this moisture-requiring form was limited to protected areas on the leeward sides of elevations. The temperature and rainfall, as indicated by the flora, suggest a climate like that in the north central United States. The recurrence of an identical flora in several horizons may indicate the destruction of the earlier forests during epochs of volcanic activity and their gradual development during the favorable conditions of intervalcanic epochs.

At 12.30 p. m. the meeting adjourned to the Michigan Union, where a complimentary luncheon was served to the members of the various scientific societies in attendance.

PRESIDENTIAL ADDRESS

At 2.30 p. m. the members convened to hear the address of Dr. W. D. Matthew, retiring President of the Paleontological Society, entitled

RECENT PROGRESS AND TRENDS IN VERTEBRATE PALEONTOLOGY

PRESIDENTIAL ADDRESS BY W. D. MATTHEW

Following the presidential address, the reading of papers in general session, with Dr. Matthew in the chair, was resumed. An account by the author of new helmet-crested dinosaurs from Alberta, illustrated by lantern slides, proved most interesting to all the members.

NEW SPECIES OF CRESTED TRACHODONT DINOSAUR

BY W. A. PARKS

(Abstract)

The genus *Stephanosaurus* was established by Lambe for the reception of a peculiar helmet-crested dinosaur from Alberta. Brown founded the genus *Corythosaurus* for another type with more pronounced helmet-like crest.

The expeditions of the University of Toronto into the bad lands of the Red Deer River, Alberta, resulted in the discovery of two heads and parts of one body of a related form distinctly intermediate between *Stephanosaurus* and *Corythosaurus*. The new species is described as *Stephanosaurus intermedius* and the opinion is expressed that the three species should be included in the one genus, *Stephanosaurus*. A rather interesting question in priority is involved.

The following paper on the paleontology and correlation of the various formations of the Richmond group, given by the author, brought forth considerable discussion, in which Messrs. Foerste, Parks, Ulrich, Ami, Bassler, and Sardeson took part.

SOME FAUNAL CORRELATIONS OF THE RICHMOND

BY W. H. SHIDELER

(Abstract)

The "Maquoketa" faunas of northeastern Illinois, eastern Wisconsin, and the upper peninsula of Michigan are well represented in Indiana, where they are found in strata of the Elkhorn beds.

These "Maquoketa" faunas constitute a fairly complete recurrence of the Fernvale fauna, but have essentially nothing in common with the typical Maquoketa of Iowa, Minnesota, and northwestern Illinois.

The typical Maquoketa was deposited in an embayment which apparently never had direct communication with the provinces to the east, and most of it is probably younger than anything in the Cincinnati region.

A paper on the correlation of Mohawkian formations in Tennessee and Kentucky was then presented by the author, who, in outlining the scope of his remarks, asked the members to delay judgment upon a recent publication on the same subject until further facts had been printed. The author then presented many valid reasons for this request.

RELATIONS AND OVERLAPS OF ORDOVICIAN FORMATIONS IN KENTUCKY AND TENNESSEE

BY E. O. ULRICH

President Matthew then, in the few minutes remaining of the afternoon session, presented a digest of the following paper:

STRATIGRAPHY OF THE SNAKE CREEK FOSSIL QUARRIES AND THE CORRELATION OF THE FAUNAS

BY W. D. MATTHEW

(Abstract)

The Snake Creek fossil quarries, 20 miles south of Agate, Sioux County, Nebraska, were discovered by H. J. Cook and the writer in 1908. They have yielded a great quantity and variety of vertebrates of later Tertiary age, mostly fragmentary, but including a considerable number of skulls and more or less complete skeletons. Mammals, and especially three-toed horses, are the most abundant.

Field observations and study of the collections indicate that three distinct faunas are represented and a fourth less clearly distinguishable, as follows:

- | | |
|--|-------------|
| ? 4. <i>Pliohippus leidyani</i> zone (doubtful): | } Lower |
| 3. <i>Hipparion affine</i> zone: | |
| 2. <i>Merychippus paniensis</i> zone: | } Pliocene. |
| 1. <i>Merychippus primus</i> zone: | |
- Late Middle or Upper Miocene.
- Early Middle Miocene.

The pockets from which the great bulk of the material has come are channel-beds excavated in and partly contemporary with fine-grained muddy sandstones, to which the name of Sheep Creek beds was applied when first found. These appear to be back-water sediment corresponding in age to horizons 1 and 2 of the channel-bed series. No back-water facies has been recognized for the Pliocene channel-beds (No. 3). These are overlain by eolian dune-sands, which constitute the top of the formation and are considerably compacted near the old surfaces. These eolian beds contain a scanty Pliocene fauna, doubtfully separable from No. 3.

The American Museum Expedition of 1922 secured a large collection from the channel-bed facies of the *M. primus* zone.

At 5.30 p. m. the Society adjourned until the following day.

Friday evening, at 7 o'clock, at the Michigan Union, the members attended the annual dinner of the Geological Society of America and affiliated societies.

SESSION OF SATURDAY, DECEMBER 30

At 9.30 Saturday morning the Society met in general session, with President Matthew in the chair. The first paper of the program was illustrated by the recently completed geologic map of the Franklin quadrangle in central Tennessee and by lantern slides.

EMBAYMENTS AND OVERLAPS IN CENTRAL TENNESSEE

BY E. S. BASSLER

(Abstract)

On account of incomplete knowledge, paleogeographic maps can seldom be made with great accuracy. By a combination of the Columbia folio map of Hayes and Ulrich and the geological map of the adjoining Franklin quadrangle, just completed by the writer, the geology of a considerable area in central Tennessee is now available in much detail and the distribution of the formations can be plotted in the form of paleogeographic maps. Such maps show that certain formations, as the Richmond, Brassfield, and New Providence, occupy embayments in the old Nashville dome, while the Lowville, Leipers, Bigby, Cannon, and other formations show broad overlaps generally to the east or to the west, caused probably by oscillation of the area.

Convincing data as to the Richmond age of the Arnheim formation of the Ohio Valley, hitherto believed by some to belong to the Maysville group of the Ordovician, were presented in the following paper, which was discussed by various members of the Society:

THE BASAL RICHMOND OF THE CININNATI PROVINCE

BY W. H. SHIDELER

(Abstract)

The top of the Maysville (Mount Auburn) is everywhere, in Ohio, Indiana, and Kentucky, separated from the base of the Richmond (Arnheim) by evidences of a stratigraphic break. This appears to be due merely to a cessation of deposition, as there is nowhere in the Cincinnati province any evidence of post-Maysville and pre-Richmond erosion.

In Ohio and Indiana the fauna of the lower or Sunset subdivision of the Arnheim seems, on superficial examination, to consist of a distinct Maysville element (largely recurrent Corryville), plus a Richmond element. Upon close examination the recurrent Corryville forms are found to be mostly undescribed species. The Richmond element appears, not at the *Dinorthis carleyi* zone in the middle, but at the base. Here it appears everywhere except in the more southern exposures in Kentucky, where the strata are largely barren of fossils.

President Matthew then presented for the author an abstract of three papers dealing with problems in vertebrate paleontology, as follows:

CARNIVOROUS SAURISCHIA IN EUROPE LATER THAN THE TRIAS

BY F. VON HUENE

CONTRIBUTION TO THE VOMER-PARASPHENOID QUESTION

BY F. VON HUENE

*LINES OF PHYLETIC AND BIOLOGICAL DEVELOPMENT OF THE
ICHTHYOPTERYGIA*

BY F. VON HUENE

A paper on the fauna found in the sandstone making the rim of Goshen Hole, Wyoming, showing its relation to the Leptauchenia beds elsewhere was given by the next speaker and a spirited discussion of the subject followed.

MIOCENE BEDS ABOUT GOSHEN HOLE, WYOMING

BY F. B. LOOMIS

A preliminary notice concerning some ostracoderm remains found in shale associated with the Monroe formation in Ohio was the subject of the next paper, in which the author pointed out clearly and illustrated by lantern slides the relation of the material to the described genera of ostracoderms of America and Great Britain and discussed the stratigraphy of the occurrence. Further discussion by Messrs. Tilton and Bassler.

PRELIMINARY REPORT CONCERNING SOME NEW OSTRACODERMS FROM OHIO

BY J. E. CARMAN

An explanation of the origin of the many growth layers found in such fossil organisms as stromatoporoids, bryozoa, and certain corals was suggested in the next paper, which was illustrated by lantern slides.

THE PROBLEM OF FOSSIL MULTILAMELLAR INVERTEBRATES

BY E. S. BASSLER

(Abstract)

In the course of studies upon Cretaceous multilamellar cyclostomatous bryozoa by F. Canu and the writer, it was discovered that the various superposed lamellæ originated in certain tubes which proceeded unchanged from the preceding lamella and which by their proliferation gave rise to all the surrounding cells of the same layer of zooecia. These generative tubes occur at stated intervals and mark off the surface in more or less regular areas of growth. It is suggested that the monticules and maculae of Paleozoic bryozoa

originated in some such way and that other multilamellar organisms owe their growth to similar methods.

An account of American rhinoceroses and the evolution of one genus, well illustrated by lantern slides, was next presented by the author. Discussion by Messrs. Loomis and Matthew.

AMERICAN RHINOCEROSES AND THE EVOLUTION OF DICERATHERIUM

BY E. S. TROXELL

(Abstract)

Scarcely any animal seems more exotic to America than does the rhinoceros. Limited at present to Asia and Africa, we have every reason to believe that they originated in America. In our own continent we can trace the line or lines of descent from *Hyrachyus* and allied forms of the middle Eocene through to the Pliocene, where the family becomes extinct. Horns were developed in the early Miocene, but their incipient beginning is noted in the Eocene. *Diceratherium*, the "two-horned beast" described by Marsh, is clearly related to *Canopus*, and by gradual steps its change from that genus can be traced until it reached its splendid development in the late Oligocene. This alone offers convincing proof of the law of evolution.

The following papers were then read by title:

PRESENT STATUS OF THE OZARKIAN AND CANADIAN SYSTEMS

BY E. O. ULRICH

MARINE EOCENE HORIZONS OF WESTERN NORTH AMERICA

BY BRUCE CLARK

SOOKE FORMATION OF SOUTHERN VANCOUVER ISLAND

BY BRUCE CLARK AND RALPH ARNOLD

EVOLUTION OF STROPHEODONTA DEMISSA (CONRAD) IN THE SNYDER CREEK SHALES OF MISSOURI

BY E. B. BRANSON AND JAMES S. WILLIAMS

(Abstract)

The evolution discussed in this paper took place while 30 feet of shales were being deposited. At the base of the Snyder Creek shales *Stropheodonta demissa* (Conrad) showed variational tendencies in the following directions: toward long hingeline and short hingeline; thick shell and thin shell; great convexity and flatness; fine plications and coarse plications; strongly projecting umbo and retreating umbo; narrowness and great width; well developed fold and sinus.

The following species evolved: *S. callawayensis* Swallow: Shell thick, coarsely plicate, hinge longer than greatest width of shell. *S. boonensis* Swallow: Shell thick, coarsely plicate, strongly convex. *S. equicostata* Swallow: Shell thin, hinge shorter than greatest width of shell, finely plicate. *S. cymbiformis* Swallow: Shell thin, hingeline very short, finely plicate, umbo projecting prominently behind hingeline. *S. inflexa* Swallow: Shell thick, hingeline shorter than greatest width of shell, umbo projecting prominently behind hingeline. *S. navalis* Swallow: Shell thick, coarsely plicate, very convex, imperfectly developed carinate fold.

The University of Missouri has more than 2,000 specimens of Snyder Creek stropheodonts and series have been arranged showing minute variations from *S. demissa* (Conrad) to each of the species listed above. The intermediate grades are rare, while there are large numbers of the typical forms.

All of the new species disappeared before 50 feet of Snyder Creek shales had been deposited.

The Society then adjourned.

REGISTER OF THE ANN ARBOR MEETING, 1922

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AMERICAN AND EUROPEAN TERTIARY BRYOZOA

BY

F. CANU AND R. S. BASSLER

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BY F. CANU AND R. S. BASSLER

(Read before the Paleontological Society December 27, 1923)

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INTRODUCTION

The comparison of the bryozoan faunas of Europe and North America is very difficult for several reasons: First, the rock series are incomplete and never in strict conformity. Second, the European publications are much scattered and do not always correspond to the richness of the formations considered. France especially, with strata enormously rich in bryozoa, has insufficient literature. Third, the hesitations of classification, which commence only when one tries to adjust them, increase the causes of uncertainty. Finally, most of the Tertiary faunas of America and Europe originated in totally different areas. We are able, therefore, to give at this time only an approximate view of the subject.

EARLY TERTIARY BRYOZOAN FAUNAS

In Europe the bryozoan fauna of the Lower Eocene is unknown, for there were then lagoon conditions incompatible to the development of these organisms. Only the Montian has been studied heretofore by Pergens and has furnished a strange mixture of Cretaceous and Eocene forms, the determination of which must be revised.

¹ This paper is one of the series composing a "Symposium on the correlation of the Tertiary formation of southeastern North America, Central America, and the West Indies with the Tertiary formations of Europe."

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Near the base of the Aquia formation, in Maryland, the glauconitic sand of the Upper Marlboro section, a most unusual deposit, contains bryozoa and other fossils indicative of the high seas, with nothing comparable to the series of superposed deposits. The fauna so far collected is essentially Cretaceous. The Cretaceous and Eocene deposits of Maryland and New Jersey, being more northern, are in consequence most comparable with the known European deposits. But the association, *Euritina*, *Cribrilina*, *Coscinopleura*, *Lunularia*, *Heteropora*, and *Ceriopora*, is essentially Cretaceous in Europe since the Cenomanian. Nothing reveals a deposit of Eocene age. The malacological fauna of the Aquia following the glauconitic sand is rigorously that of the famous locality of Bracheux, in France; it is certainly Thanetian, as Heilprin has always regarded it.

The bryozoan faunas of the Midwayan have been collected in Arkansas, Alabama, and Georgia. The affinities are still Cretaceous, with the generic association of *Smittipora*, *Euritina*, *Bathosella*, and *Ascosævi*, but the presence of Recent genera, *Galeopsis* and *Gephyrotes* (appearing in the Cretaceous Vincentown marl), *Gastropella* (occurring at the top of the Cuisian), *Hippoporina* and *Anarthropora* indicates the beginning of the Eocene series as in Europe. But as we have not observed all the genera collected in the London clays and in the superior sands of Cuise-Lamotte in France, we can synchronize the American Midwayan only with the French Sparnacian and the base of the Cuisian.

In regrettable contrast, when really important bryozoan faunas appear in Europe we find nothing in America which can be rigorously compared to them. Between the Midwayan and the Claibornian we have only a small, insignificant fauna found in the Wilcoxian. Here the Cretaceous forms have almost disappeared. The appearance of the genera *Cystisella*, *Rhamphostomella*, *Aimulosia*, *Lunularia*, and *Adeonellopsis* indicate that this stage is in correlation with the superior Cuisian of France and perhaps with the base of the Lutetian of western Europe.

The Claibornian has Lutetian affinities with *Exechonella* (from the Lutetian of southern France), *Adeonellopsis* (from Lutetian of Paris basin), and with the association of *Trochopora*, *Otionella*, *Porella*, and *Schizorthosecos*. However, the rich development of the Adeonidæ in the Paris basin has no equivalent in America. The presence of *Vibracellina* and of *Holoporella* and the consideration that almost all the species pass into the Jacksonian permits us to consider the Claibornian as the equivalent of the superior Lutetian and the Auversian.

The fauna from the Jacksonian is one of the most beautiful in the world. Almost all the Recent genera are represented. It is very close,

although much richer than that from the European Priabonian. There are some common species, namely, *Rhamphostomella brendolensis*, *Gemellaria prima*, *Callopora tenuirostris*, *Conopeum hookeri*, *Acanthodesia savarti*, *Centronea micropora*, *Lichenopora verrucosa*, etcetera. There are some genera which appear simultaneously—*Scrupocellaria*, *Houzeauina*, *Cellaria*, *Mastigophora*, *Retepora*, etcetera.

OLIGOCENE BRYOZOA

The Vicksburgian, much less rich, has, nevertheless, afforded an important fauna, very comparable to the German Oligocene deposits, which form in reality only a single stage. There are some common species, as *Lichenopora goldfussi*, *Stephanosella entomostoma*, *Smittina strombecki*, *Smittina angulata*, etcetera. The presence of species of *Metrarabdotos* (from the Latdorfian) leaves no doubt as to the synchronism.

The general evolution on the two continents is not identical. Thus *Nellia* and *Heterocella*, abundant fossils in the Lutetian, are known only in the Vicksburgian. Likewise *Retepora*, *Cellaria*, *Tubucellaria*, *Peristomella*, and *Bracebridgia*, appearing in the Lutetian epoch, have yet been observed only in the Jacksonian. Finally *Trypostega*, appearing in the American Midwayan, is known only in the European Miocene.

BRYOZOA OF THE AMERICAN MIOCENE

The comparison of Miocene deposits of bryozoa in America and Europe is not actually possible. The first reason is geographic. In Europe the more important Miocene deposits are found to the north of the fortieth parallel, while in America they are situated to the south. The second reason is bibliographic.

In America the Miocene and Pliocene strata with bryozoa are rare and rather poor, although well studied. In Europe, on the contrary, and especially in France, they are very numerous and of great richness, but little studied. In order to appreciate these important faunas, we have at our disposal only the old monographs of Reuss (Tortonian), of Busk (Pliocene), and the lists of Seguenza and Neviani (Italy) and the few recent papers of Canu and Duvergier (Miocene of Bordeaux). The faunas of Touraine and the Sahelian of Oran, with a wonderful richness, are known only from the manuscript notes of Canu extracted from a work that may never be published for lack of time and resources.

The American Lower Miocene Tampa and Alum Bluff formations furnish too few bryozoa to help in intercontinental correlation. The following American Miocene strata form two groups. In the first should be

classed the Choptank and Saint Marys formations. They present an association of genera which persist today in the temperate Atlantic. The small number of Recent species present indicates a relative antiquity for the formation, but, with the bryozoa only, it is impossible to fix the age. Possibly the association of *Cupularia* and *Theonoo*, observed in Touraine, authorizes us at least to class the Saint Marys formation near the Helvetian.

In the second group must be classed the Bowden horizon, the Yorktown formation, the Duplin marl, and the Choctawhatchee marl. Their faunas are tropical or subtropical and are closely related to the Recent fauna of the Gulf of Mexico. They are in continual regression toward the south because of constant rising of the American continent. *Velumella*, *Floridina*, *Steganoporella*, *Metrarabdotos*, and *Hippaliosina* are the most characteristic genera.

The Bowden horizon was considered for a long time in Europe as the equivalent of the Lower Miocene (Burdigalian). We have observed here 52 species, in which 16 are Recent (32 per cent), thus indicating a more recent division of the Miocene.

The faunules collected in the other formations are of unequal value and little comparable among themselves. Nevertheless, in applying the usual method of enumeration we have constructed the following small table:

	Species observed.	Recent species.	Percentage.
Choctawhatchee marl.....	22	8	36
Duplin marl.....	50	17	34
Yorktown formation.....	32	9	28

Although this method is often of little value, in this case it confirms the superposition recognized by the geologists; but it is absolutely impossible to establish any synchronism whatever with the European deposits formed in a much colder zone. The species pass easily from one stage to another, even into the Pliocene, and there is apparently little arrest in sedimentation.

PLIOCENE BRYOZOA

From the Pliocene we have material from three localities only. They have given only 36 species. This fauna can not be compared, however, with the Miocene, which here yielded more than a hundred species. According to the percentage of Recent species, the Waccamaw marl of the Pliocene is, perhaps, the inferior horizon, and the Caloosahatchie marl, especially as developed in Munroe County, Florida, is doubtless at the top.

Proceedings of the Paleontological Society

**PROCEEDINGS OF THE FIFTEENTH ANNUAL MEETING OF
THE PALEONTOLOGICAL SOCIETY, HELD AT WASH-
INGTON, D. C., DECEMBER 27-29, 1923.**

R. S. BASSLER, SECRETARY

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VOL. 35. PP. 169-200

MARCH 30, 1924

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R. S. BASSLER, *Secretary*

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SESSION OF THURSDAY, DECEMBER 27

The preliminary business meeting, held usually at the first session of the Society, was postponed until Friday morning in order that the members could meet in joint session with the Geological Society of America on Thursday morning. At 12.30 the address of Dr. T. Wayland Vaughan, retiring President of the Paleontological Society, was delivered before all the affiliated societies in the auditorium of the Interior Building. As the presidential address formed the introductory paper of the symposium planned as the main feature of the meeting, an outline of its principal features is here presented.

CRITERIA AND STATUS OF CORRELATION AND CLASSIFICATION OF TERTIARY DEPOSITS

PRESIDENTIAL ADDRESS BY T. WAYLAND VAUGHAN

(Abstract)

This paper briefly reviews the essential principles utilized in geologic correlation, with particular reference to Tertiary deposits. After defining the

geologic terms formation, member, group, and stage, the necessity of type localities for stratigraphic units is emphasized and the construction of standard stratigraphic sections and time scales is discussed. The biologic method of correlation is considered in some detail and the defects of both the Lyellian method and inference from supposedly known stratigraphic ranges of species and genera are pointed out. The effects of barriers on geographic distribution, unequal rates of evolution in different areas, and rates and means of migration from one area to another are discussed in their bearing on problems of correlation, and more detailed and comprehensive investigation of the duration of the free-swimming larval stages of marine organisms is urged. The value of interdigitating terrestrial and marine organisms in correlation is stated.

The previous attempts to correlate American with European Tertiary formations are briefly outlined; the defects and the causes of the defects of these attempts are discussed and suggestions for remedying them are made.

The importance of the American Tertiary formations in solving problems of world-wide correlation of Tertiary formations is stated, and more thorough and comprehensive investigations of the stratigraphy and paleontology of Central America and the West Indies is specially urged.

The principal units of the classification of European Tertiary deposits are listed, and reference to the original publication, the source of the name, the type locality, and the general features of each limit are given. The paper closes with a similar list of units in the classification of the Tertiary deposits of southeastern North America, Central America, and the West Indies.

The societies then adjourned for luncheon.

At 2 p. m. the Paleontological Society met in the conference room of the Director, United States Geological Survey, and, with Doctor Vaughan in the chair, proceeded with the reading of the symposium papers.

SYMPOSIUM ON THE CORRELATION OF THE TERTIARY FORMATIONS OF
SOUTHEASTERN NORTH AMERICA, CENTRAL AMERICA, AND THE
WEST INDIES WITH THE TERTIARY FORMATIONS OF EUROPE

The first paper was presented by the author. Discussion was reserved until the presentation of all papers had been completed.

TERTIARY TERRESTRIAL VERTEBRATE HORIZONS OF NORTH AMERICA

BY W. D. MATTHEW

In the unavoidable absence of the author, the second paper had to be read by title.

*INTERDIGITATION OF AMERICAN TERTIARY TERRESTRIAL VERTEBRATES
WITH MARINE DEPOSITS*

BY J. C. MERRIAM

The next speaker discussed the geographic distribution of living pelagic vertebrates and the geologic occurrence of North American Tertiary cetaceans, comparing the various American faunas with those of Europe.

TERTIARY PELAGIC VERTEBRATES OF EASTERN NORTH AMERICA

BY REMINGTON KELLOGG

The floras of the various stages of the Tertiary of southeastern North America were compared with those of Central America, the Antilles and northern South America, and the present status of their correlation with one another, with the standard marine section, and with the Tertiary floras of Europe were discussed in the next paper.

AMERICAN TERTIARY TERRESTRIAL PLANTS AND THEIR INTERDIGITATION WITH MARINE DEPOSITS

BY E. W. BERRY

President Vaughan then presented the data afforded by the larger foraminifera and corals.

AMERICAN AND EUROPEAN TERTIARY LARGER FORAMINIFERA AND CORALS

BY T. WAYLAND VAUGHAN

(Abstract)

Most of the genera of larger foraminifera common to Europe and America have similar, or nearly similar, stratigraphic ranges on the two continents, as is shown by the following data on their stratigraphic distribution in America. No large *Nummulites*, such as are common in Eurasia, are known in America. Small species, probably not true *Nummulites*, range from deposits of middle Eocene age to middle and perhaps uppermost Oligocene. *Operculina* ranges from middle Eocene to the Tuxpan Miocene. *Heterostegina* ranges from upper Eocene to the top of the Culebra formation, probably Aquitanian. Species referred to the nomenclatorially invalid genus *Orthophragmina* range from Claibornian or slightly lower Eocene to uppermost Eocene. The species referable to *Asteriacites* of Schlotheim and similar forms are known only in the upper Eocene. *Cycloclypeus* and *Assilina* are unknown in America. Lepidocycline foraminifera of *Lepidorbitoides* facies are abundant in the upper Eocene; true *Lepidocyclina* ranges from upper Eocene to the horizon of the Emperador limestone, probably the equivalent of the Aquitanian. *Helicolepidina* is known only in the upper Eocene of America. *Miogypsina* is known in the upper part of the Culebra formation, the Emperador limestone, and the Anguilla formation, in deposits probably the equivalent of the European Aquitanian. *Dictyoconus* ranges from the middle Eocene Plaisance limestone of Haiti to the middle Oligocene Glendon limestone in Florida. *Sorites* ranges from the Culebra formation to Recent. *Alveolina* is common in the Eocene of Jamaica, and is represented by a small species in younger deposits.

Lepidocyclus s. s. (type *L. mantelli*) in America seems to attain its maximum development earlier than in Europe. In America this development is upper Eocene and lower and middle Oligocene, but the genus is represented in deposits probably the equivalent of the Aquitanian.

The principal tie points between the American and European coral faunas are, as I have already published, the upper Eocene Saint Bartholomew limestone with the Priabonian of Italy and the lower part of the Antigua formation and the Glendon limestone of Florida and Georgia with the Rupelian of Castel Goberto and other places in northern Italy.

A paper by Dr. G. Stefanini, of Florence, Italy, newly elected Correspondent of the Society, dealing with the correlation as shown by the echinoids, was read by C. W. Cooke.

AMERICAN AND EUROPEAN TERTIARY ECHINOIDS

BY G. STEFANINI

The value of the bryozoa in intercontinental correlation and other features of geologic interest exhibited by these organisms were indicated in a paper read by R. S. Bassler.

AMERICAN AND EUROPEAN TERTIARY BRYOZOA

BY F. CANU AND R. S. BASSLER

The remaining papers of the symposium dealt with the molluscan evidence. The first of these was concerned with the early Tertiary faunas.

AMERICAN AND EUROPEAN EOCENE AND OLIGOCENE MOLLUSCS

BY C. WYTHE COOKE

(Abstract)

An important tie point in the correlation of the American and European formations is the faunal break between the Eocene and Oligocene. Less than 9 per cent of the molluscs in the Red Bluff clay (lower Oligocene) are survivors from the Eocene, and the proportion for the entire Vicksburg group is considerably less. Fewer than 5 per cent of the molluscs in the large Sannoisian fauna are Eocene species. Both above and below this break the generic assemblages on both sides of the Atlantic are similar.

Direct comparison of American with European forms has been hampered by the lack of representative collections from many foreign localities, but many similar, possibly identical species can be cited. Some of these are characteristic Eocene or Oligocene species, but range through several formations. In general, therefore, precise correlations between American and European formations based only upon our present knowledge of the molluscs are not practicable.

The later Tertiary mollusca were discussed in the next paper.

COASTAL PLAIN AND EUROPEAN MIOCENE AND PLIOCENE MOLLUSCS

BY JULIA GARDNER

(Abstract)

The fauna of the Chipola marl at the base of the Alum Bluff and of the Miocene approaches more closely to a tropical fauna than does any other Miocene fauna of the southeastern United States. On the basis of the stratigraphic position of Central American and West Indian faunas of the same age the relationship of the Chipola to the Burdigalian fauna of southwestern France may be traced. With the gradual cooling of the waters in the later Alum Bluff, many of the tropical species disappear and the affinity of the later Alum Bluff to the Burdigalian of southern Europe becomes more obscure. The most pronounced faunal break in the Neocene of the East Coast occurs at the close of the Shoal River. The tropical species are swept away by the influx of cooler waters from the north and supplanted by a fauna remarkably homogeneous from Maryland to Florida and comparable to that of north-central Europe. In the later Miocene there is a gradual readjustment and an approximation to modern conditions. A warm current allowed the southern faunas to reestablish themselves, to a certain extent, as far north as Hatteras. A comparison of the Duplin and Choctawhatchee may be made with the Sarmation and Tortonian of southern Europe, but the correlation of the Yorktown with the Upper Miocene of Europe is less direct. The relationship of the East Coast Pliocene faunas to those of the Pliocene of Europe is closely analogous to the relationship of the East Coast Recent and European faunas.

The final paper of the symposium, illustrated by numerous charts, was then presented.

WEST INDIAN, CENTRAL AMERICAN, AND EUROPEAN MIOCENE AND PLIOCENE MOLLUSCS

BY W. P. WOODBRING

(Abstract)

The Miocene deposits of the West Indies and Central America contain rich tropical faunas of probably 2,000 species of molluscs, of which not more than half have been described. Pliocene deposits so far explored have yielded only a meager fauna. These West Indian and Central American faunas are compared with essentially similar faunas of two classic European Tertiary basins, the Aquitaine basin of France and the Piedmont basin of Italy.

The composition of the American and European faunas, based on the genera, is graphically shown on charts. The American faunas are predominantly West Indian. Their most striking exotic element is a group of genera now living only in the Pacific Ocean or in the Indo-Pacific region. The European faunas have a much larger percentage of exotic genera. The largest group of living exotic genera is West Indian. Other exotic genera are living both in the West Indies and along the West African coast; others only along the coast of West Africa, especially along the Senegalese coast. The European

faunas have an even larger percentage of Pacific and Indo-Pacific genera than the American faunas, but for the most part these genera in the two regions are different.

Almost all the exotic genera in the European deposits now living in the West Indies, or in both West Indian and West African waters, are common West Indian and Central American Miocene fossils. For this reason there is a striking resemblance between these American and European Miocene faunas. This resemblance reaches its culmination in the Helvetian faunas, as is shown in a graph.

A general discussion of the problems brought out in the symposium followed the concluding paper, and the subject of the smaller foraminifera which had not been considered was especially reviewed.

At 5 p. m. the Society adjourned until the following day.

Thursday evening at 7.30 the members met in the auditorium of the Interior Building with the other affiliated societies to hear the address of Mr. David White, retiring President of the Geological Society of America and former President of the Paleontological Society. Mr. White's address was entitled "Gravity observations from the standpoint of local geology."

Following this address the members were tendered a complimentary smoker by the Geological Society of Washington.

SESSION OF FRIDAY, DECEMBER 28

President Vaughan called the fifteenth annual meeting of the Society to order in business session, at 9.15 a. m., December 28, in the Director's conference room, and after welcoming the members to Washington requested the reading of the report of the Council.

REPORT OF THE COUNCIL

To the Paleontological Society in fifteenth annual meeting assembled:

The Society's business for the year has been transacted by two formal meetings of the Council and by correspondence.

SECRETARY'S REPORT

To the Council of the Paleontological Society:

Meetings.—The proceedings of the fourteenth annual meeting, held at Ann Arbor, Michigan, December 28-30, 1922, have been printed in volume 34, number 1, of the Bulletin of the Geological Society of America, pages 121-142. The Council's proposed nominations for officers for

1924 was mailed to the members on March 1, 1923. At the same time it was announced that the fifteenth annual meeting would be held at Washington, D. C., December 27-29, 1923, as guest of the Geological Society of Washington, and that a symposium on the "Correlation of the Tertiary formations of southeastern North America, Central America, and the West Indies with the Tertiary formation of Europe" was proposed for this meeting.

Membership.—The Society has lost four of its members during the year by death—Mr. Thomas A. Bostwick, well known for his long service in the care of the paleontological collections at Peabody Museum, Yale University, and Mr. Edgar E. Teller, General Anthony W. Vogdes, and Mr. George F. Matthew, three active students of invertebrate paleontology who have done much to further the science by their work and publications. Six new members have just been elected to the Society and five nominations are awaiting consideration at this meeting. Five of our members have been elected this year to Fellowship in the Geological Society of America and one Fellow of the latter Society has requested election to our own Society. The result of these various changes leaves a total number of members at the end of 1923 of 239.

• *Publications.*—The publications of the Society for the year consist of the Proceedings, the Presidential address, and three papers on vertebrate paleontology, all appearing in the Bulletin of the Geological Society of America.

Dr. R. S. Lull represented the Society at the Joseph Leidy Commemorative Meeting, held at the Philadelphia Academy of Natural Sciences, December 6, 1923.

The Council appointed Dr. Arthur Hollick, on March 10, 1923, as the representative of the Society on Botanical Abstracts, succeeding Dr. E. W. Berry, whose term had expired.

During the year the Council has cooperated with the Geological Society of America in an effort to more logically classify the papers presented at the meeting by the various affiliated societies, and especially to arrange a program in which papers of general interest would not conflict. Several circular letters regarding this subject were sent to the members during the course of the year. It is believed that the program as arranged for the present meeting, providing for joint sessions of the affiliated societies for the presentation of papers of general interest, obviates most of the points under criticism.

Pacific Coast Branch.—The meeting of the Pacific Branch of the Paleontological Society was held on September 18, at the Los Angeles Museum of History, Science and Art, Exposition Park, with Vice-President

A. O. Woodford presiding. Ten papers dealing particularly with the stratigraphy and paleontology of the West Coast were presented.

Respectfully submitted,

R. S. BASSLER,

Secretary.

WASHINGTON, D. C., *December 26, 1923.*

TREASURER'S REPORT

To the Council of the Paleontological Society:

The Treasurer begs to submit the following report of the finances of the Society for the fiscal year ending December 22, 1923:

RECEIPTS

Cash on hand December 23, 1922.....	\$802.22
Membership fees.....	288.00
Interest, Connecticut Savings Bank.....	29.64
	<hr/> \$1,119.86

EXPENDITURES

Secretary's office:

Secretary's allowance.....	\$50.00
Clerical aid.....	25.00
Office expenses.....	48.00
	<hr/> \$123.00

Treasurer's office:

Treasurer's allowance.....	\$25.00
Postage	4.00
	<hr/> 29.00

Geological Society of America:

Printing programs, etcetera.....	\$9.25
Reprints	28.00
	<hr/> 37.25
	<hr/> 189.25

Balance on hand December 22, 1923.....	<hr/> \$930.61
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Net increase in funds.....	\$128.39
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Outstanding dues (1922, 4; 1923, 24).....	84.00
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Final statement of retiring Treasurer, 1911-1923:

Received from W. D. Matthew, 1911.....	\$141.91
To be paid to C. O. Dunbar, 1923.....	930.61

Net increase in funds.....	<hr/> \$788.70
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Liabilities due at this time, none.

Respectfully submitted,

RICHARD S. LULL,

Treasurer.

NEW HAVEN, CONNECTICUT, *December 22, 1923.*

APPOINTMENT OF AUDITING COMMITTEE

Following the report of the Council, President Vaughan appointed Messrs. Resser and Twenhofel as a committee to audit the Treasurer's accounts.

ELECTION OF OFFICERS AND MEMBERS

The result of the election of officers for 1924 and of new members was then read as follows:

OFFICERS FOR 1924

President:

E. W. BERRY, Baltimore, Maryland

First Vice-President:

E. H. BARBOUR, Lincoln, Nebraska

Second Vice-President:

FRANK SPRINGER, Washington, D. C.

Third Vice-President:

F. M. ANDERSON, Berkeley, California

Secretary:

R. S. BASSLER, Washington, D. C.

Treasurer:

CARL O. DUNBAR, New Haven, Connecticut

Editor:

WALTER GRANGER, New York City

NEW MEMBERS FOR 1924

JOHN H. BRADLEY, JR., 5640 Woodlawn Avenue, Chicago, Illinois.

HARRY S. LADD, Old Science Hall, University of Iowa, Iowa City, Iowa.

ERWIN R. POHL, U. S. National Museum, Washington, D. C.

MERRILL A. STAINBROOK, Old Science Hall, University of Iowa, Iowa City, Iowa.

FRANKLIN E. VESTAL, Department of Geology, Agricultural College, Mississippi.

BRADFORD WILLARD, Department of Geology, Brown University, Providence, Rhode Island.

NEW NOMINATIONS AND ELECTION TO MEMBERSHIP

The following five nominations to membership arriving too late for printing on the ballot had received the approval of the Council and were now presented for action by the Society. In turn the qualifications of each nominee were presented to the members. All received election upon vote:

- T. D. A. COCKERELL, 905 Tenth Street, Boulder, Colorado. Professor of Zoology, University of Colorado. Proposed by R. S. Bassler and E. O. Ulrich.
- EUSTACE L. FURLONG, 1031 Glendora Avenue, Oakland, California. Curator of Mammals, Museum of Paleontology, University of California. Proposed by Ralph W. Chaney and Chester Stock.
- MURRAY O. HAYES, Assistant Professor of Geology, Brigham Young University, Provo, Utah. Proposed by E. O. Ulrich and R. S. Bassler.
- ALLEN TESTER, graduate student, Department of Geology, University of Wisconsin, Madison, Wisconsin. Proposed by W. H. Twenhofel and R. C. Moore.
- J. B. WINSTANLEY, 2818 Orchard Avenue, Los Angeles, California. Proposed by Ralph W. Chaney and Chester Stock.

Mr. F. Julius Fohs, elected to Fellowship in the Geological Society of America, requested enrollment in the membership of the Paleontological Society. Upon vote, Mr. Fohs was duly elected a member.

ELECTION OF CORRESPONDENTS

President Vaughan then reported that the Council favored the election as Correspondents of three distinguished foreign geologists and paleontologists—Dr. F. A. Bather, of England; Prof. G. Stefanini, of Italy, and Dr. G. E. Pilgrim, of India—in view of their important contributions to our science. The work of Doctor Bather was reviewed by R. S. Bassler, that of Doctor Pilgrim by President Vaughan and W. D. Matthew, and of Professor Stefanini by E. W. Berry. Upon vote, these three scientists were unanimously elected.

- Dr. F. A. BATHER, British Museum (Natural History), London, England.
- Prof. G. STEFANINI, Real Istituto di Geologia e Paleontologia, Florence, Italy.
- Dr. G. E. PILGRIM, Superintendent, Geological Survey of India, Calcutta, India.

NECROLOGY

President Vaughan then recalled the Society's loss by death during the year of four members, and first requested Professor Dunbar to present some remarks upon the life of Mr. Bostwick. Professor Dunbar spoke as follows:

MEMORIAL OF THOMAS A. BOSTWICK

Thomas Attwater Bostwick was born in New Haven, Connecticut, November 29, 1859, the son of Frederick L. and Elizabeth Rowland Bostwick. At the age of eighteen he entered the service of Professor Marsh, enrolling at the same time as a special student in Sheffield Scientific School, and six years later, two years after the erection of Peabody Museum at Yale, joined its staff as an assistant. This was the beginning of a long and faithful service which he fulfilled until his very last days. During the earlier years he accompanied Marsh and Beecher on several fossil-hunting expeditions, and throughout the intervening years he journeyed to many parts of the country to pack and ship the numerous important natural history collections that from time to time have been generously given to Yale. He was the only member of the staff whose services were continuous from the founding of the Museum until the razing of the old building in 1917, and his knowledge of our vast collections was, therefore, irreplaceable.

In 1888 Mr. Bostwick married Emily Farnsworth, who survives him. His gentleness of manner and thoughtfulness of others were outstanding characteristics of a personality that knew only friends, and his quiet and unselfish devotion to his work rendered his services in Peabody Museum almost invaluable.

Dr. W. D. Matthew then spoke of his father's life and work. His remarks are summarized below.

MEMORIAL OF GEORGE F. MATTHEW

George Frederic Matthew was born at Saint John, New Brunswick, Canada, August 12, 1837, of United Empire Loyalist parentage, the family having come originally from Dundee, Scotland. From the age of sixteen until a few years before his death he was on the staff of the Saint John Custom Service as surveyor of the port at the time of his retirement. He was interested as a boy in natural history, especially geology and botany. With Charles Frederic Hartt and other young men he founded the Steinhammer Club, later developed into the Natural History Society of New Brunswick. Many of the results of his earlier geologic work were included in Dawson's *Acadian Geology*. After confederation, the Geological Survey of Canada undertook the mapping of the provinces, and Matthew was employed on field-work for several seasons, mostly with Bailey and Ellis, in southern New Brunswick. The great Saint John fire of 1877 was a heavy loss to him and destroyed his library, herbarium, and geological collections, unpublished notes and records, and he limited himself after that time to work in Cambrian paleontology, subsequently extending it to later Paleozoic formations, but chiefly in and near Saint John.

He was generally regarded as one of the principal contributors to the earlier knowledge of the geology of New Brunswick, and especially to the paleontology of the Cambrian of that region, its glacial and postglacial history, and the difficult and still unsettled problems of its later Paleozoic formations. His views as to the age of the latter, based upon the stratigraphic evidence, brought down upon him the denunciations of the official school of paleobot-

anists; but as none of his critics have re-examined the stratigraphy, the matter should be held *sub judice*.

Although not a college graduate, my father was widely read and well informed in many branches of natural history. He had an honorary doctorate from Laval University, was a charter member of the Royal Society of Canada, a Fellow for many years of the Geological Society of London and the recipient of its Wollaston Medal; a corresponding member of the old New York Lyceum of Natural History and of its successor, the Academy of Sciences; but his chief interest lay with the work of the local Natural History Society, in which he took an active part at all times, and for many of his later years as president of the Society. He was elected a member of the Paleontological Society in 1920. He died at Hastings-on-Hudson, New York, April 17, 1923, in his eighty-sixth year. He married, in 1868, Katherine M. Diller, of Brooklyn, New York, and had a family of six sons and two daughters. The oldest son, who has the honor to contribute this brief notice, follows in his father's footsteps.

Personally, my father was a somewhat reserved and silent man, upright, modest and unselfish, and deeply imbued with the love of nature. He was held in high respect and affection by those who knew him well.

The Secretary presented the following résumé of the life of Mr. Edgar E. Teller, which had been kindly furnished by Mrs. Teller.

MEMORIAL OF EDGAR E. TELLER

Edgar Eugene Teller was born in Buffalo, New York, August 3, 1845, the son of George D. and Susan Brown Teller. He received his education in Buffalo's public and private schools, attending the Central High School, and from there going to Lewiston Academy, at Lewiston, New York, where he received an appointment to Annapolis from the Hon. John Ganson, M. C.; but before he was to enter on his studies he met with an accident, breaking his wrist, thereby incapacitating him for naval service.

The Civil War came on about this time, and the young man desired to enlist, but was refused, due to his youth. Finally he was allowed to go and the boy served through two years under Capt. Theo. D. Barnum, Infantry, B Company, 74th Regiment. At the call for troops at the first of Gettysburg raid they went to the front, and after serving on the field for some time the regiment was sent up the Hudson River, stopping at all places on the way to Sing Sing, returning to New York City, performing important duty at these several points in quelling draft riots; then back to Buffalo, where they were mustered out.

He then entered the employ of his father and several years later, in 1869, he married Marie E. Deeves, of Buffalo. Leaving the family home in Buffalo, Mr. Teller went to Milwaukee, Wisconsin, and entered the employ of Plankinton & Armour, pork packers, in 1875, and shortly afterward was appointed buyer for the firm at the Milwaukee livestock yards. He continued in this capacity successively with Plankinton & Armour, John Plankinton & Company, Cudahy Brothers, and Cudahy Brothers Company, until he retired in 1915, after an unbroken connection with the latter-named company and its

predecessors for forty years. After the death of his only son in that same year, he returned to Buffalo to make his home.

It was during his early days in Milwaukee that he first became interested in geology. In going from his home to business he had occasion to walk through a quarry—a short cut, where he would stop and watch the men at work—and as time went on made the acquaintance of Doctor Day, of Wauwatosa; Doctor Hoye, of Racine; Mr. Thomas A. Greene, and Mr. Chas. E. Monroe, of Milwaukee, all prominent collectors.

Aside from his business association, Mr. Teller took a deep interest in local paleontology, in which field of science he was an authority. He was also interested in other departments of natural history, and particularly in archeology. Elected as a member of the Wisconsin Natural History Society March 3, 1885, he became very active in the archeological section of it.

Mr. Teller was made recording secretary of the Wisconsin Historical Society December 19, 1887, and was elected president of the Society in 1889, and re-elected to the presidency at various intervals almost up to the time of leaving Milwaukee.

By the year 1899 the Archeological Section of the Natural History Society had a very active membership, and largely through the efforts of Mr. Teller and coworkers the membership increased to such strength that in the year 1901 it separated from the parent Society and was incorporated as "The Wisconsin Archeological Society."

It is at present a strong and active Society, and in the twenty-three years of its existence has accomplished much in the way of exploration, recording, and preserving of Wisconsin Indian antiquities. Mr. Teller was one of the active and enthusiastic members and accompanied all of its early field explorations and researches, especially in Milwaukee and Waukesha counties of Wisconsin.

Mr. Teller invariably attended and presided over all of the Wisconsin Archeological Society meetings, and with other members helped to lay the firm foundations upon which the long and successful labors for the public and anthropological science has been based.

A group of Indian effigy and burial mounds, designated as the "Teller Group," were located near the Milwaukee cement mills, at the northern limits of the city, and were named at that time in honor of Mr. Teller's work in their discovery. A part of this group is still in existence. The group is fully described and illustrated in the Bulletin of the Wisconsin Natural History Society for the years 1900-1902.

Some of the most notable works contributed to the Society by Mr. Teller are described in papers and records listed hereunder.

March 14, 1887. Paper read by Edgar E. Teller, "Geology and paleontology of eastern Wisconsin." Wisconsin Natural History Society Bulletin.

April-May, 1899. "The fauna of Devonian formation at Milwaukee, Wisconsin." Printed in the Journal of Geology, volume 7, number 3. "The Teller group of mounds in Milwaukee County." Introduced to the Society by Edgar E. Teller in May, 1899. Described in Bulletin of the Wisconsin Natural History Society, volumes 1 and 2, 1900-1902.

"Notes of the fossil fish-spine *Phlyctanacanthus Telleri*." Published in the Wisconsin Natural History Society Bulletin, volumes 3 and 4, 1903-1906.

"An operculated gastropod from the Niagara formation of Wisconsin." Transactions of the Wisconsin Academy of Sciences, Arts, and Letters, volume 16, part 11, 1909-1910.

"A synopsis of the type specimens of fossils from the Paleozoic formations of Wisconsin." Bulletin of the Wisconsin Natural History Society, volumes 9, 10, 1911, 1912.

On Mr. Teller's return to Buffalo, in 1915, he was elected vice-president of the Buffalo Society of Natural Sciences.

His death, on July 19, 1923, interrupted his work of reclassifying his large collection, but the contributions from his pen, published in periodicals dealing with geological field-work, will remain as a record of his service in this sphere.

During his life Mr. Teller gave the University of Chicago over one hundred thousand specimens as a working collection for the students. He also gave to the Public Museum, in Milwaukee, and to the American Museum of Natural History, in New York, large numbers of specimens; to the latter several type specimens, among them a new species and a new genus of Phyllocarida (*Entomocaris Telleri*). Ten thousand selected specimens were presented to the Buffalo Society of Natural Science.

Dr. Resser then gave the following brief account of General Vogdes' life:

MEMORIAL OF ANTHONY W. VOGDES

General Anthony Wayne Vogdes was born at West Point, New York, in 1843, being descended from General Anthony Wayne on his mother's side. His father and grandfather were generals in the United States Army. He entered the Civil War as a drummer, but was soon commissioned a second lieutenant. After the Civil War he decided to remain in the army, and as a second lieutenant he was detailed to guard the Union Pacific Railroad during building. It was while on this service that he began both his library and collection of fossils.

General Vogdes rose to the rank of brigadier-general before retirement, when he moved to San Diego, California, where he was formerly stationed. His means were never large, so that the splendid library accumulated by him represents much personal sacrifice. This library, now the property of the San Diego Society of Natural History, of which General Vogdes was president for fifteen years, includes about 40,000 titles. Many of the books are beautifully bound by General Vogdes himself, who was very proficient in this work. The fossil collections, also left to the same Society, contains a very large and fine assemblage of trilobites.

General Vogdes published a number of papers on paleontology, but is best known for his bibliographic works on Paleozoic crustacea.

The reading of papers was then commenced, with President Vaughan in the chair.

PRESENTATION OF PAPERS

The first paper of the session delivered by the author brought forth a discussion from several members.

SUBDIVISIONS OF THE CAMBRIAN

BY C. E. RESSER

(Abstract)

A threefold subdivision of the Cambrian strata is usually made, following a long-standing custom. These subdivisions are designated as Lower Cambrian characterized by trilobites of the family Mesonacidae, Middle Cambrian containing *Paradoxides*, and Upper Cambrian with *Dikelocephalus*. This subdivision was made in Sweden for the rather specialized conditions obtaining there, but is applicable beyond the faunal province to which Sweden belongs.

The existence and character of what may be called the Atlantic Province is usually not appreciated. For practically all of Cambrian time and during long intervals in later periods the animals living in this province were all confined to it. The boundary or barrier line, traced approximately, runs north through central Massachusetts, through New Brunswick and central Newfoundland, thence across the Atlantic, possibly, with an embayment reaching Greenland, definitely crossing England in southern Scotland, then across Scandinavia somewhere north of Lake Mjosen. The Cambrian faunas of Esthonia, Bohemia, Sardinia, France, Spain, Morocco, and Portugal belong in this province. Only one undoubted transgression of this barrier is now known, with a second indicated. Therefore no exact correlation is possible between the Cambrian strata within and without this province.

The type section for the Lower Cambrian, as it is now used, is in Nevada. There is a general agreement of the faunas present with the more northerly and eastern beds assigned to the same period. No genera cross the barrier into the Atlantic Province, so that except for the members of the same families there is no agreement. Another problem as yet unsolved is the significance of the phyllopods. Recently an interesting group of phyllopods similar to those formerly found only in the Middle Cambrian has been obtained in British Columbia. Opinions differ regarding the phyllopod faunas in New York and in the Atlantic Province in New Brunswick and Portugal as to whether they belong in the Middle or Lower Cambrian. The question of this boundary is therefore an open one just now.

The type section for the Middle Cambrian is the beds in the Atlantic Province which contain *Paradoxides*. As this genus is completely absent outside of this province no limits can be set to this portion of the Cambrian.

The type section for the Upper Cambrian is that of Wisconsin. This has proven quite satisfactory for North America. In this portion of the Cambrian there is one connection between the American and Atlantic Province faunas. In the lower part of the Conasauga formation of Alabama true *Olenus* and *Agnostus reticulatus* occur associated with certain typical American forms. This is the first definite transgression of the barrier that makes the Atlantic Province so exclusive. We can then assume that most of the *Olenus* series and the Upper Cambrian of the American type section are equivalent in age. Definite limits can not, however, yet be drawn.

Recently obtained data indicate that some of the upper beds formerly included in the Cambrian must be regarded as Ozarkian. Sufficient study has not yet been given to this matter to fix this boundary definitely at all points.

The threefold subdivisions of the Cambrian, while not satisfying all conditions nor allowing the drawing of sharp boundaries, must be retained for the present, recognizing, however, the particular unsolved problems.

A paper on Ordovician stratigraphy was then presented by the junior author, who illustrated it with lantern slides.

OCCURRENCE OF THE COLLINGWOOD FORMATION IN MICHIGAN

BY R. RUEDEMANN AND G. M. EHLERS

(Abstract)

The Collingwood formation is typically exposed at Ottawa and in southeastern Ontario. The most western exposures of the formation, which so far have been noted, occur in the vicinity of Little Current, on Manitoulin Island, Ontario.

The occurrence of Collingwood strata farther westward in the Northern Peninsula of Michigan is indicated by the presence of *Ogygites latimarginatus* (Hall) syn. *Ogygites canadensis* (Chapman) and other characteristic Collingwood fossils, collected from blocks of shale and limestone in the drift near the southern limits of Newberry, Luce County, Michigan.

The Collingwood age of the blocks of shale and limestone, found in the drift near Newberry, is suggested by their lithological character as well as their faunal content. This is particularly true in the case of the blocks of shale. In Ontario the Collingwood consists of alternate beds of shale and limestone. It seems very possible that this lithological character of the Collingwood may hold westward as far as the region a short distance north of the southern limits of Newberry, where, unfortunately, the formation is covered by drift.

The Collingwood seems to represent a differential development of a part of the upper Utica of New York, which may indicate either a provincial separation from the Utica sea farther south or, more probably, a separate invasion from another (northeastern) direction. According to the evidence presented in this paper, this invasion extended farther west—at least to the Newberry, Michigan region—than has been hitherto believed.

Interesting occurrences of Pleistocene mammals in Mexico were described in the following paper, presented by the author and illustrated by lantern slides:

SOME PLEISTOCENE MAMMALS AND THEIR OCCURRENCE IN MEXICO

BY E. L. FURLONG

A stratigraphic paper, illustrated by lantern slides, was next on the program.

GEOLOGICAL FEATURES OF THE EASTERN HIGHLAND RIM OF TENNESSEE

BY R. S. BASSLER

(Abstract)

The Highland Rim surrounding the Central Basin of Tennessee offers many splendid sections for the study of the formations and of their distribution.

Recent investigation of the Eastern Highland Rim showed marked stratigraphic differences from the rim west of the Central Basin. For example, on the east the geological section comprises only the Hermitage and Cannon formations of the Ordovician and the Chattanooga, Fort Payne, and Warsaw divisions of the Mississippian, while in marked contrast on the western rim the same geologic interval develops the Hermitage, Bigby, Cannon, Catheys, and Leipers formations of Ordovician age, the Waynesville, Fernvale, and Osgood divisions of the Silurian, and the Chattanooga, Ridgetop, New Providence, Fort Payne, and Warsaw divisions of the Mississippian.

Topographically the Eastern Rim is quite distinct, for it usually forms a sharp escarpment, with many narrow ravines cutting back into the rim and having their origin in sink-hole structures.

A description of a huge pelecypod, probably an *Inoceramus* from the Cretaceous of the Mackenzie Valley, Canada, was given in the next paper.

AN ENORMOUS CRETACEOUS PELECYPOD

BY G. S. HUME

A most interesting and curious new dinosaur was then described, with lantern-slide illustrations.

NEW PLATED DINOSAUR FROM THE RED DEER RIVER

BY W. A. PARKS

Dr. W. D. Matthew, at the request of President Vaughan, then gave an interesting extemporaneous account of the work of the American Museum of Natural History Expedition in Mongolia.

EXPLORATION FOR FOSSIL REMAINS IN MONGOLIA

BY W. D. MATTHEW

(Abstract)

The Third Asiatic Expedition of the American Museum of Natural History, American Asiatic Association, and Asia Magazine has put in two winters of paleontological work in China and two summers in Mongolia. The geologic and physiographic results in Mongolia are reported upon by Berkey and Morris before the Geological Society. The paleontologic work in charge of Walter Granger was extraordinarily successful. A very large collection of Upper Pliocene mammals was obtained from fissure deposits near Wanhshine, on the upper Yang-tse-kiang, including skulls of *Stegodon*, *Rhinoceros*, a gigantic tapir, gaur, tiger, sand-badger, bamboo-rat (numerous), langhur monkey, several kinds of antelope, etcetera. No human or pre-human remains were found associated with this fauna, although they were to be expected. Two summers' field-work in the desert of Gobi showed that region to be rich in fossils, including a number of faunas of Cretaceous and Tertiary age not yet fully correlated. Two complete skeletons and several more fragmentary specimens of a small primitive Iguanodontoid dinosaur were secured in 1922,

and in 1923 a great series of 72 skulls and 12 skeletons of a small ceratopsian dinosaur, together with 25 eggs, probably of this species, were obtained at one locality, and at another a great collection of bones and partial skeletons of various kinds of dinosaurs. All these are probably early to middle Cretaceous, but not yet certainly correlated. A skull of the gigantic rhinoceros *Baluchitherium* was found in 1922, associated with a fauna of some thirty species of smaller mammals, mostly rodents, carnivora, and insectivora of Lower Oligocene age, in part new, the rest related to the Phosphorites fauna of France and the White River fauna of this country. An older horizon explored chiefly in 1923 yielded skulls of *Protitanotherium*, a gigantic masonychid creodont, two or more lophiodonts, and other interesting types. Fragmentary remains representing older Eocene faunas were also discovered, as well as other faunas of later Tertiary age.

These results show that in Central Asia is a region as rich in fossils as the western United States, although not so accessible. A large part of its fauna is wholly new and the affinities of other parts provide the needed clues to the problems of origin and dispersal of many races of animals. It will undoubtedly repay many years' exploration. The chief difficulty is the heavy cost of operations in that region, so remote from railroads and roads. Profitable collecting is possible only in a large way, with wide-cast preliminary reconnaissance, followed by intensive collecting in promising areas, and requires an elaborate, well planned, and expensive organization.

In the absence of the authors, the following papers were read by title:

OZARKIAN-CANADIAN UNCONFORMITY

BY E. O. ULRICH

NEW PEABODY MUSEUM AT YALE UNIVERSITY

BY R. S. LULL

BEEKMANTOWN GRAPTOLITES FROM UTAH

BY T. H. CLARK

NEW OZARKIAN FORMATION IN MISSOURI

BY E. O. ULRICH

OLIGOCENE HICKORY NUTS

BY E. L. TROXELL

COMPARISON OF THE BRIDGE CREEK FLORA WITH THE LIVING REDWOOD FOREST

BY R. W. CHANEY

FEATURING THE GEOLOGY OF PARKS

BY E. L. TROXELL

FORT CASSIN FAUNA

BY E. J. FOYLES

At 12.30 p. m. the Society adjourned.

Friday afternoon was spent in joint session with the Geological Society of America, when the following program of stratigraphic papers was presented, some of them by title only:

GEOLOGIC SECTION ACROSS THE COAST RANGES OF CALIFORNIA

BY GEORGE D. LOUDERBACK

FRANKLIN MOUNTAINS

BY MERTON YARWOOD WILLIAMS

*STRATIGRAPHY OF THE CRETACEOUS-EOCENE TRANSITION BEDS IN
EASTERN MONTANA AND THE DAKOTAS*

BY W. T. THOM, JR., AND C. E. DORBIN

CHAGRIN FORMATION OF OHIO

BY GEORGE HALCOTT CHADWICK

EROSION BY SOLUTION AND FILL

BY WILLIS T. LEE

NEW FORMATION IN THE TAMPICO EMBAYMENT REGION

BY J. A. CUSHMAN AND EARL A. TRAGER

STRUCTURES IN THE SLATES OF NORTHEASTERN PENNSYLVANIA

BY CHARLES H. BEHRE, JR.

GEOLOGY OF LEVIS, QUEBEC

BY THOMAS H. CLARK

PROPOSED STRATIGRAPHIC SECTION AND CODE

BY GEORGE H. ASHLEY

SUGGESTIONS FOR THE IMPROVEMENT OF OUR GEOLOGIC TERMINOLOGY

BY ELIOT BLACKWELDER

UPPER ORDOVICIAN AT TORONTO, ONTARIO

BY W. A. PARKS

EARLIER SILURIAN FORMATIONS OF PENNSYLVANIA

BY CHARLES K. SWARTZ

KANSAS PERMIAN UNCONFORMITY

BY GEORGE HALCOTT CHADWICK

ORISKANY LIMESTONE IN ILLINOIS

BY T. E. SAVAGE

Friday evening at 6.30 the members attended the annual dinner of the Geological Society of America and affiliated societies, when a program prepared by the Pick and Hammer Club, of Washington, furnished a considerable part of the entertainment.

SESSION OF SATURDAY, DECEMBER 29

As the reading of papers had been completed on Friday, no regular session was held on this day. Interested members attended the meetings of the Geological Society of America and the Mineralogical Society; others visited the laboratories and exhibits of the United States National Museum, while still others studied the geology of the Piedmont Plateau and Atlantic Coast Plain, in the vicinity of Washington, under the guidance of a local member.

REGISTER OF THE WASHINGTON MEETING, 1923

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MINUTES OF THE MEETING OF THE PACIFIC BRANCH OF THE
PALEONTOLOGICAL SOCIETY

The meeting of the Pacific Branch of the Paleontological Society was called to order by Vice-President A. O. Woodford at 9 a. m., September 18, 1923, at the Los Angeles Museum of History, Science, and Art, Exposition Park. The following papers were then read:

PRESENTATION OF PAPERS

*FOSSIL CONTENT OF THE SAN RAFAEL LIMESTONE OF THE SAN RAFAEL
MOUNTAINS, SANTA BARBARA COUNTY, CALIFORNIA*

BY M. C. ISRAELSKY

MARINE EOCENE HORIZONS OF WESTERN NORTH AMERICA

BY B. L. CLARK

*STUDY OF THE FAUNAL AND STRATIGRAPHIC RELATIONS OF THE MIDDLE
AND LOWER MIOCENE OF THE SANTA ANA MOUNTAINS,
SOUTHERN CALIFORNIA*

BY C. D. MESERVE

CRETACEOUS DEPOSITS OF THE NORTHERN ANDES

BY F. M. ANDERSON

FOSSIL DIATOMS OF CALIFORNIA FROM A HISTORICAL STANDPOINT

BY C. DALLAS HANNA

The meeting then adjourned for luncheon.

At 2.15 p. m. the meeting was again called to order by Vice-President A. O. Woodford and the following papers were read:

*PROTESTING THE SPECIES-MAKER: THE POINT OF VIEW OF THE PRACTICAL
PALEONTOLOGIST*

BY A. J. TIEJE

WESTERN EXTENT OF THE PAINTED DESERT FORMATION AND ITS FAUNA

BY C. L. CAMP

*CLASSIFICATION AND RELATIONSHIP OF THE EDENTATES OF RANCHO LA
BREA*

BY CHESTER STOCK

*PROGRAM FOR FURTHER STUDY OF SUCCESSION OF FAUNAS AND FLORAS
IN THE JOHN DAY REGION OF EASTERN OREGON*

BY JOHN C. MERRIAM

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